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Final Work

Student
Ankush Gaharwar
ankushgaharwar@gmail.com

Supervisor
Michele Russo

A.Y. 2022-2023 Ankush Gaharwar - Cosmic Kaksh Master of Science in PRODUCT AND SERVICE DESIGN

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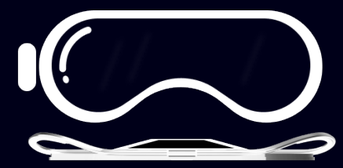
Ankush Gaharwar
Supervisor - **Michele Russo**

COSMIC KAKSH

VR-based furniture design in Zero-Gravity Environments



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VR-based furniture design in Zero-Gravity Environments

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Cosmic Kaksh - That translates to a room in cosmos is my thesis work that explores the challenges and potential solutions for dining in a zero-gravity environment, emphasizing the role of Virtual Reality (VR) in enhancing the experience. The research focuses on the unique conditions of zero-gravity environments, highlighting the differences in dining experiences compared to Earth, where typical dining concepts are inapplicable due to the absence of gravity. This environment leads to distinct challenges in managing floating food and drinks, the necessity of specially packaged food, and the importance of crumb management for safety and hygiene.

Virtual Reality emerges as a key tool in this research, providing immersive experiences that simulate the zero-gravity environment. This technology is especially valuable for astronaut training and designing space habitats. The thesis aims to design a dining table suited for zero gravity, addressing practical issues like object management and enhancing astronauts' mental well-being. The study includes a comprehensive analysis of existing solutions, material selection, technological considerations, and the development of virtual simulations and prototypes.

The research's scope extends beyond the mere functionality of a dining table; it seeks to create a space that fosters social interaction and improves astronauts' quality of life in space. The ultimate goal is to develop a comprehensive solution that encompasses various aspects of life in space, including dining, movement, and interaction, all facilitated by Virtual Reality.

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PART ONE
RESEARCH

01
INTRODUCTION

Living in a zero-gravity environment is tricky, because of weightlessness everything floats and so do you. There is no proper orientation and that's why in international space center there is no up or down, unlike Earth where everything has to be put on the floor (due to gravity) this concept does not apply in space. Imagine you are in a room where the rules of up-and-down just does not exist. So, in this unique environment, the concept of floor and ceiling become irrelevant. What we would in general, call a wall can just as easily serve as a place to stick your laptop.

The typical dining table will not work in this scenario, and the usual way to approach this problem is to build a furniture will also not work we, that's why where we are simulation comes into play as it helps in understanding the unique State of weightlessness. This opens up a whole new level of possibilities. We can approve the table from many directions, so it should be like that and approachable design approachable from married directions.

According to British Council's Article: What's life like on an international space station?

By Professor Mark McCaughrean

The International Space Station (ISS), a sizable structure about 100 meters across, presents unique challenges for astronauts. Despite its size, much of the space is occupied by equipment, requiring astronauts to navigate in zero gravity, which can be disorientating. Key traits for success in this environment include technical expertise and the ability to work well in a team in close quarters, as big personalities are not always conducive to the teamwork needed in such an isolated environment.

Life on the ISS is regimented, with astronauts following a schedule set to Greenwich Mean Time (GMT) and experiencing 16 sunrises and sunsets per day due to the station's rapid orbit around Earth. Their activities range from individual research to collaborative spacewalks, and are closely monitored from Earth. For relaxation, astronauts often gather in the cupola, a module with large windows, to view Earth.

Communication with families is maintained through email and videoconferencing, facilitated by the station's proximity to Earth. Sleeping arrangements involve individual cubicles with sleeping bags to prevent floating.

Dining in space is adapted to zero gravity conditions. Bread is avoided due to the potential for crumbs to spread, and meals typically consist of canned heat-stabilized food or rehydrated powdered foods, with occasional fresh produce delivered by resupply vehicles. Hygiene is managed with limited water, liquid soap, and dry shampoo.

So the typical dining table will never work in this scenario and also the usual way to approach this problem will not also work. That's where Virtual Reality will come into play as it helps in understanding the unique state of weightlessness.

1.1 Context of Zero-Gravity Environments

Technically ISS has microgravity, but it is close to zero. The mass of everything up there is Zero. Nothing has any weight that means we can lift anything without breaking a sweat. Conditions like this leads to major loss of body mass and astronauts are required to exercise (resistance based) regularly. Everything floats everywhere and astronauts are living in a cylinder. They don't have matters as it is of no need. They can just put themselves in a restraining sleeping bag and sleep. Astronauts are one of the most mentally tough people around most of them. They are from military background and have been through one of the toughest of trainings and yet sometimes vast space gets the better of them, and in future this mental pressure will become bigger as the missions will become longer. In zero gravity everything floats and we need materials like Velcro to hold them on to. But what Astronauts hold on to?

Understanding zero gravity is very important for future space exploration. As missions potentially extend to Mars and beyond, it is important to know how to support astronauts' physical and mental health in space. This includes designing effective living spaces and tools for use in an environment where traditional concepts of up and down are irrelevant.

Thus, zero gravity presents a fascinating yet challenging environment. It reshapes everyday activities and significantly impacts the human body and mind. Understanding and adapting to these challenges is integral to preparing for life in space, where the absence of gravity redefines living and working conditions.

1.2 Challenges of Dining in Zero Gravity

The act of dining in space presents a huge challenge, a stark contrast to Earth-bound experiences. This segment explores the peculiarities of handling and consuming food in a weightless setting. It discusses the intricacies of food packaging, preparation, and consumption in space, underscoring the need for innovative dining solutions tailored to zero gravity.

Dining in zero gravity, such as on a space station, brings a unique set of challenges that are quite different from eating on Earth. It's not just about missing the pleasure of a sit-down meal; it's a fundamental rethinking of how to handle, consume, and even enjoy food in a weightless environment.

Food Behavior in Zero Gravity

Floating Food: In zero gravity, everything floats, including food and drinks. Imagine your soup or pasta floating away from your bowl, or water forming little spheres in the air. This makes the simple act of getting food from a plate to your mouth quite tricky.

Packaging and Eating: Most foods in space are specially packaged to prevent them from floating away. Astronauts often eat from tubes or packets where they can squeeze food directly into their mouth. They use special magnetic cutlery and trays to keep things in place.

Preparing Meals

No Cooking: Traditional cooking methods like frying or boiling are impossible in zero gravity. There's no stove or fire for heat, and without gravity, hot air doesn't rise, so food doesn't cook evenly. Most space food is pre-cooked and just needs reheating, often in a microwave-like oven.

Limited Choices: The variety of food available is limited. While space agencies try to provide a range of options, the need for long shelf life and special packaging reduces the variety astronauts can enjoy.

Eating Experience

Taste Changes: Astronauts have reported changes in taste while in space, possibly due to fluid shift towards their head in zero gravity. Foods may taste blander, so they often prefer spicier, more flavorful meals.

Social Aspect: Dining is also a social activity, an important aspect for astronauts living in close quarters. Sharing meals is one way they bond and maintain good mental health. So, the challenge is not just about eating but about creating a pleasant dining experience in space.

Safety and Hygiene

Crumb Management: Crumbs from bread or crackers can float away, getting into equipment or ventilation systems, which can be dangerous. That's why tortillas are often used instead of bread.

Clean-Up: Without sinks or running water, cleaning up is a challenge. Wipes and towels are commonly used for cleaning utensils and surfaces.

Nutritional Balance

Maintaining Nutrition: Ensuring astronauts receive the right balance of nutrients is crucial, especially on long missions. Space food must be nutritionally balanced to keep astronauts healthy.

Designing for Zero Gravity Dining

Innovative Solutions Needed: The unique challenges of zero gravity require innovative approaches to dining. Designing tools and methods that make eating in space easier and safer is an ongoing process, involving not just space agencies but also researchers and designers.

In conclusion, dining in zero gravity goes beyond just eating. It encompasses handling and consuming food in a weightless environment, ensuring nutritional and safety requirements are met, and maintaining the social and psychological well-being of astronauts. As we venture further into space, refining our approach to dining in zero gravity becomes increasingly essential.

1.3 Introduction to Virtual Reality (VR)

The potential of virtual reality is huge in enhancing the zero-gravity environment. Astronauts usually train themselves underwater, which requires a lot of effort, time and resources. Even though the underwater training is great, it can't be done frequently and quickly. So, to attain those 10,000 hours of training VR Simulation of zero gravity environment is the best tool. Additionally, we can make a zero gravity VR simulation with VR mounted on a motion platform like a flight simulator.

This simulation can also help in improving and developing the dining table and the experience around it.

So Virtual Reality emerges as a groundbreaking tool, offering immersive experiences that blend the real with the virtual. This chapter introduces VR, elucidating its mechanism, types, and applications. The focus will be on VR's potential in simulating and enhancing experiences in zero gravity, particularly for astronaut training and space habitat design.

1.4 Objectives and Scope of Research

The objective of this is to design a dining table for the zero-gravity environment. It should cater to all the problems that have been faced previously and not just be a place to eat but also a place to gather and mingle with other astronauts. The objective is to come up with a better design solution with the help of VR simulation that helps us understand the zero-gravity environment better. Moreover, I want to emphasize the human part of human space exploration. The dining table is something that is used every day, this makes it the best place to implement important things that improves the quality-of-life of an on duty astronaut. So overall, my aim is to make astronaut centric design, which involves the dining table, the spoon, the holding railing and the socks they wear. We cannot just design the dining table in isolation. I will explain why as we go through some pre-existing designs and works.

In this thesis, I will cover the dining table of zero gravity which will solve problems like objects floating away, cleanliness, and many more with the help of VR. We will see how the table functions and how approachable it is from different directions. We will then see that since orientation does not matter the table can be fixed on the wall or at the bottom. The mental well-being of astronauts will also be explored. And how a new design can help them bring people together and interact more. We will solve some dining issues and some movement issues as well. Overall, it will be an exploration which revolves around dining, moving and interacting with the help of virtual reality.

Thus, the research aims to conceptualize a dining table suited for zero gravity, integrating VR to augment the dining experience. It seeks to address practical challenges such as managing floating objects, ensuring the table's functionality, and enhancing astronauts' mental well-being through design. The scope encompasses the design and usability of the table in a zero-gravity setting, focusing on astronaut needs and psychological aspects.

2. State of the Art (Scenario Analysis/ Research Space)

The dining table design in the International Space Station (ISS) has several notable aspects, both positive and negative, based on its unique environment and the constraints of space travel:

Positive Aspects

1. Adapted to Zero Gravity: The design of the dining area in the ISS is adapted to the unique conditions of zero gravity. This includes features that prevent food from floating away and allow astronauts to eat in a weightless environment.
2. Functional and Compact: Given the limited space in the ISS, the dining areas are designed to be functional and compact. The Russian segment originally had the only galley area, equipped with a table for three, a water system for hydrating food, and a food warmer. [https://www.mentalfloss.com/article/583166/kitchen-on-iss-international-space-station]
3. Adaptability for Increased Crew: With the increasing crew size, a second galley area was added in the U.S. segment, located in Node 1 (Unity), to accommodate more astronauts and provide additional dining options.

Negative Aspects

1. Lack of Human Factor in Design: The current design of the dining area in the ISS has been criticized for focusing more on functionality and less on the human aspect of dining. This includes the over-engineered nature of the Galley Table, which, while stable, might be excessively engineered for a zero-gravity environment. [https://www.core77.com/posts/125916/Fantastic-Industrial-Design-Student-Work-Space-Station-Dining-Table]
2. Clutter and Mess
3. Segregation During Meal Times: The multiple-galley setup, with different segments having their own dining areas, can lead to segregation during meal times. This was observed with different groups of astronauts dining separately in their respective segments or spacecrafts, which could impact the communal and social aspect of dining together.

2.1 Zero-Gravity Living Environments

When we talk about zero-gravity living environments, we're referring to places where the force of gravity is either very weak or feels like it's nonexistent. The most common example of this is in space, particularly on spacecraft or space stations like the International Space Station (ISS). Let's dive into what these environments are like and why they're important:

What is Zero Gravity?

A Weightless World: In zero gravity, everything is in a state of weightlessness. Objects and people float freely because the gravitational force that keeps us grounded on Earth is absent or very weak.

How It's Experienced: Astronauts in space experience this when their spacecraft is in orbit. They're essentially in a constant state of free-fall around the Earth, creating the sensation of weightlessness.

Daily Life in Zero Gravity

Moving Around: Without gravity, walking isn't an option. Astronauts move by pushing off surfaces and floating to their destination. They often use handrails or straps to hold themselves in place.

Eating and Sleeping: Eating can be tricky since food and liquids can float away. Most food is specially packaged, and sleeping involves strapping into a sleeping bag attached to a wall.

Physical Effects: Living without gravity can affect the body. Muscles and bones can weaken without the resistance of gravity, so astronauts do regular exercises to stay fit and healthy.

The Challenges

Health Issues: Long-term exposure to zero gravity can lead to various health issues, including muscle atrophy, bone density loss, and changes in vision and fluid distribution in the body.

Mental Well-Being: Being in a confined space, away from family and the familiar comforts of Earth, can be challenging. The isolation and unusual environment can impact mental health.

Why Study Zero-Gravity Environments?

Space Exploration: As we aim for longer space missions, perhaps to Mars or further, understanding how to live and work in zero gravity is crucial. We need to ensure astronauts can stay healthy and perform their tasks.

Designing for Space: Living in space requires rethinking everything from furniture to tools. Without gravity, everyday objects need to work differently. For instance, how do you design a table or a toilet that works well in zero gravity?

Scientific Research: Space provides a unique laboratory. Studies in zero gravity have led to breakthroughs in various fields, from medicine to materials science.

In summary, zero-gravity living environments offer a unique and challenging setting for human activities. Understanding and adapting to these environments is essential for the future of space exploration and has broader implications for science and technology. It's a field that continues to evolve as we push the boundaries of what's possible in space.

2.2 Advancements in Virtual Reality (VR)

Virtual Reality (VR) has come a long way since its early concepts. Today, it's a rapidly evolving technology that offers immersive experiences, blurring the lines between the physical world and the digital realm. Let's explore the advancements in VR in simple and human terms:

Early Days of VR

Conceptual Beginnings: VR started as a concept several decades ago. The initial ideas were about creating an environment where users could feel as if they were in a different world.

Primitive Technology: Early VR systems were basic and often bulky. They had limited graphics and were not very user-friendly. These systems were mainly used in research labs and a few specialized applications.

Better, Faster Hardware: Modern VR headsets are light, comfortable, and provide high-resolution displays. This makes the VR experience much more realistic and enjoyable.

Advanced Graphics: Today's VR graphics are incredibly detailed and lifelike. This realism is key to making VR experiences truly immersive.

Motion Tracking: Current VR systems track your movements accurately. When you move your head or hands, the VR environment responds in real-time, making you feel like you're really inside the virtual world.

Wide Range of Applications

Gaming: VR has transformed gaming, offering immersive experiences where players feel like they're inside the game.

Education and Training: VR is used for training pilots, doctors, and military personnel, providing a safe environment to practice and learn.

Healthcare: VR is helping in therapy, such as treating phobias or helping with rehabilitation after injuries.

Virtual Tourism: People can explore distant places or historical sites from their homes, thanks to VR.

Accessibility and Social VR

More Accessible: VR technology is becoming more affordable and accessible. More people can buy VR headsets and use them at home.

Social Experiences: VR platforms now allow for social interactions. People can meet, play, and work together in virtual spaces, regardless of their physical location.

In conclusion, VR has evolved from a niche, experimental technology to a mainstream, versatile tool with countless applications. It's an area that continues to grow and innovate, offering experiences that were once thought to be the stuff of science fiction. As VR becomes more advanced, its impact on entertainment, education, healthcare, and social interactions is likely to increase significantly.

2.3 Integration of VR in Dining Table Design

To design the dining table for space VR is a necessary tool as it helps in Understanding the design better. We cannot understand the purpose of the design, like why a particular design is developed in a certain way without experiencing it in real life. But since we cannot experience it in reality, we try to do it in virtual reality where we integrate zero gravity simulations in the VR experience and understand the design better.

3. Project Analysis and Experiment

3.1 Analysis of Existing solution

When discussing the "Analysis of Existing Solutions" in the context of your thesis on zero-gravity dining tables and VR integration, you're essentially evaluating what's already out there. This involves looking at current designs and technologies to see how they address the challenges of dining in space. Let's explore this in simple and understandable terms:

Understanding Current Zero-Gravity Dining Solutions

Astronauts on long-duration space missions have to eat a variety of nutritious foods to stay healthy and strong. Their food is specially packaged to withstand the rigors of space travel and to make it easy to eat in a zero-gravity environment.

Types of food

1. Astronauts' food comes in a variety of forms, including: Freeze-dried foods: These foods have had all of their moisture removed, which makes them lightweight and easy to store. To eat freeze-dried foods, astronauts simply add water and rehydrate them. [Image of Freeze-dried foods for astronauts] *
2. Thermostabilized foods: These foods have been processed to make them shelf-stable, which means they don't need to be refrigerated. This makes them ideal for long-duration space missions.
3. Fresh fruits and vegetables: Astronauts are able to grow fresh produce on the International Space Station (ISS). This provides them with a variety of vitamins and nutrients that are essential for good health.

Packaging

1. Astronauts' food is packaged in a variety of ways to prevent it from floating around in zero gravity. Some common packaging methods include:
2. Retort pouches: These pouches are made of a durable plastic that can withstand high temperatures. They are often used for wet foods, such as soups and stews.
3. Pouches with Velcro closures: These pouches are easy to open and close, and they can be attached to walls or tables to prevent them from floating away.
4. Cans: Cans are a classic way to package food for space travel. They are durable and easy to stack, and they can be used for both wet and dry foods.

Methods for eating in zero gravity

1. Eating in zero gravity can be a challenge, but astronauts have developed a number of techniques to make it easier. Some common methods include:
2. Using utensils with straps: Utensils with straps can be attached to astronauts' wrists or hands to prevent them from floating away.
3. Using a tray: A tray can be used to hold food and utensils in place.
4. Eating out of pouches: Pouches can be squeezed to get the food out, and they can be resealed to prevent food from floating away. Astronauts also have access to a variety of condiments and spices to flavor their food. Some common condiments include ketchup, mustard, and mayonnaise. Some common spices include salt, pepper, and paprika which are in liquid form.

Overall, astronauts have a variety of options for food and eating in space. The food is nutritious and flavorful, and the packaging and methods for eating make it easy to enjoy meals in a zero-gravity environment.

Dining Tables in Space

Let's take a look if there are any specialized dining tables or surfaces used in spacecraft or space stations. How are they designed? Do they have features like magnetic surfaces or Velcro to keep things in place?

This is the dining table that is being used in the International Space Station, very cluttered, unorganized and small. They have two things, Velcro and elastic straps that help in attaching the food items onto the table. The dining table on the International Space Station (ISS) is a remarkable example of design adaptation to the extreme conditions of space.

Design Overview

1. Material and Construction: The ISS dining table is crafted from lightweight, durable materials that can endure space conditions and are easy to clean, a necessity for maintaining hygiene in the confined space station environment.

2. Space-Efficient Design: Given the limited space on the ISS, the dining table is designed to be compact. Features like foldability or collapsibility allow astronavuts to optimize space utilization.

3. Adaptation to Microgravity: A key challenge is ensuring stability in zero gravity. The table and items are secured using Velcro, magnets, or clamps, and the surface may be textured to prevent objects from floating away.

4. Ergonomics: Adjustable heights or angles are incorporated to accommodate various activities and different body sizes, ensuring comfort for all astronauts.

5. Safety Features: With safety as a priority, the table is designed with smooth edges and corners and made from fire-resistant, non-toxic materials.

6. Integrated Functionality: It includes compartments for utensils and food packages, drink holders, and attachment points for personal items, aiding in meal organization and preventing items from floating away in microgravity.

7. Cultural and Psychological Aspects: The design also considers the crew's cultural and psychological needs, aiming to provide a sense of normalcy and encourage communal eating, important for morale.

Advantages

:

1. Efficient Use of Space: The compact and collapsible design makes efficient use of the limited space available on the ISS.

2. Practicality in Microgravity: Features like Velcro and magnetic holders keep items secure in a zero-gravity environment, making dining and other activities more manageable.

3. Ergonomic Design: The adjustable and comfortable design accommodates various activities and body types, enhancing the well-being of astronauts.

4. Safety-Oriented: Emphasis on safety with fire-resistant materials and smooth edges reduces the risk of accidents.

5. Boosts Morale: By considering cultural and communal aspects, the dining table helps in maintaining the crew's morale and mental health.

Disadvantages

1. Limited Space: Despite its compact design, the table still occupies valuable space which is a critical resource on the ISS.

2. Maintenance Challenges: Keeping the table and its mechanisms functioning correctly in the harsh environment of space can be challenging and requires regular maintenance.

3. Limited Versatility: The table is specifically designed for the microgravity environment of space, which limits its functionality compared to Earth-based designs.

4. Cost: The specialized materials and design features necessary for space use make the table significantly more expensive than conventional dining tables.

In summary, the ISS dining table is a testament to innovative design under the constraints of space travel, prioritizing safety, functionality, and psychological well-being. However, its specialized nature does bring challenges in terms of space utilization, maintenance, versatility, and cost.

Examining VR Solutions

Current VR Applications: currently VR is widely used in many areas for example Education, Simulation, Gaming, Entertainment and Training. This also

Future Prospects

Continued Innovation: The future of VR looks bright, with ongoing improvements in technology. We can expect even more realistic graphics, better motion tracking, and more user-friendly interfaces.

Integration with Other Technologies: Combining VR with technologies like augmented reality (AR) and artificial intelligence (AI) could lead to even more groundbreaking applications.

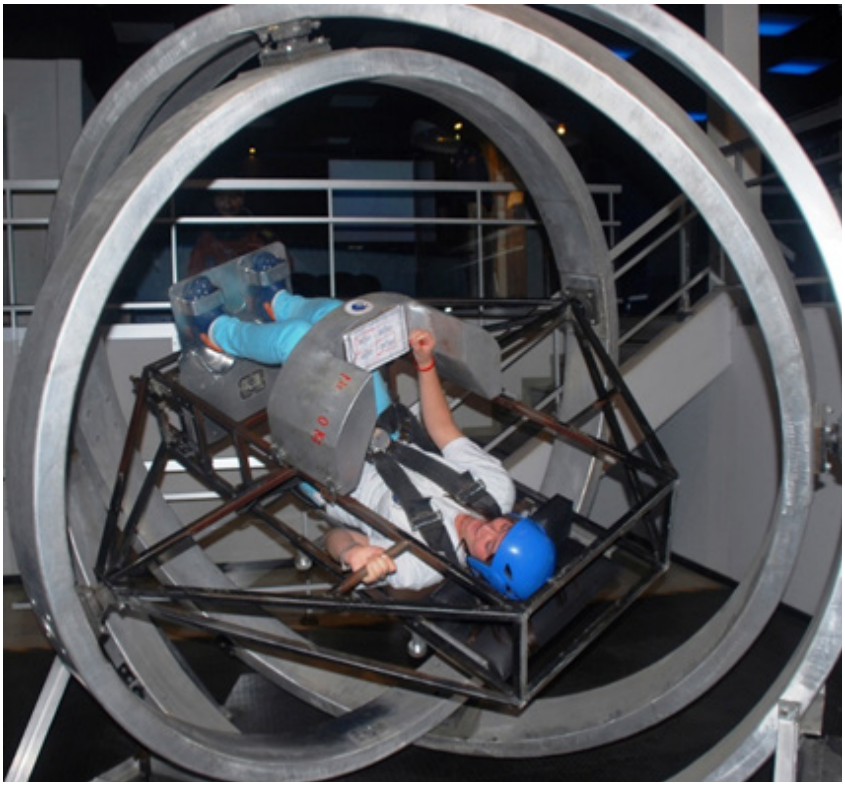
And to make zero gravity simulation more realistic we can put people with VR Headsets on a Zero Gravity Motion simulation (Like an Aerotrim) that moves and rotates according to the players in the Zero Gravity Simulation. This will also help the astronauts in training before their mission.

https://www.wired.com/2014/08/oculus-rift-birdly-fly/

https://en.wikipedia.org/wiki/Aerotrim

(An Aerotrim (also known as Multi-Axis Trainer or MAT) is a 3-axis gimbal large enough to contain a human being, used for cardiovascular workout and equilibrioception (balance) training in pilots and astronauts.)

Oculus rift birdly fly



An Aerotrim (also known as Multi-Axis Trainer or MAT) is a 3-axis gimbal large enough to contain a human being, used for cardiovascular workout and equilibrioception (balance) training in pilots and astronauts.

3.2 Geometric Study and Material Selection

In this thesis on designing a zero-gravity dining table with VR integration, the "Geometric Study and Material Selection" section plays a crucial role. This part of your research is about choosing the right shapes, sizes, and materials for your dining table to make sure it works well in a zero-gravity environment. Let's explore this in more detail:

Geometric Study

Shape and Size: The geometry of your dining table is key. In zero gravity, the usual table designs might not be effective. You need to think about how astronauts will access and use the table. Will it be circular to allow easy reach from all angles? Or will it have a different shape to better fit the space station's interior?

Ergonomics: Consider how astronauts will interact with the table. Ergonomics, which is the study of how people interact with objects, is vital. The height, angles, and edges of the table must be designed so astronauts can use it comfortably without straining or floating away.

Space Utilization: Space is limited in spacecraft. Your table design needs to be space-efficient, possibly foldable or multi-functional.

Material Selection

Key considerations of materials when designing a dining table for a space station:

1. Lightweight:
   - Aluminum: Widely used in aerospace for its light weight and strength.
   - Carbon Fiber Composites: Known for their high strength-to-weight ratio, often used in high-performance aerospace applications.
   - Titanium: Another lightweight, high-strength material commonly used in space-craft.

2. Strength and Durability:
   - Stainless Steel: Offers durability and resistance to wear and tear.
   - Aerospace-Grade Aluminum Alloys: Specifically designed for high-strength applications.
   - Kevlar-Reinforced Composites: Known for their high tensile strength and impact resistance.

3. Non-toxic and Fire Resistant:
   - Specialized Fire-Resistant Plastics: Such as PEEK (Polyether Ether Ketone), known for high heat tolerance and low smoke and toxic gas emission.
   - Ceramic Composites: Offer excellent fire resistance and are non-toxic.

4. Easy to Clean:
   - Laminated Surfaces: Easy to wipe and resistant to staining.
   - Polished Stainless Steel: Resistant to corrosion and easy to sanitize.
   - Non-porous Acrylics: Resist bacteria and stains, easy to maintain.

5. Magnetic or Velcro-like Properties:
   - Magnetic Stainless Steel: Can be used to keep magnetic utensils or tools in place.
   - Velcro Patches: Integrated into table surfaces to attach items securely in zero gravity.

6. Space Compatibility:
   - Aerospace Aluminum and Titanium: Do not outgas and are compatible with space conditions.
   - High-Performance Plastics: Such as PEEK or Ultem, which are stable in vacuum and resistant to radiation.

Selecting the right combination of these materials ensures the table is functional, safe, and durable in the unique conditions of space.

Cleaning and Maintenance: Consider how easy it is to clean and maintain the materials. In a zero-gravity environment, cleaning spills or crumbs is more challenging, so materials that are easy to wipe down and don't trap dirt are preferable.

Balancing Factors

Balancing Aesthetics and Function: While functionality is key, the aesthetic aspect can't be ignored. The table should not only be practical but also visually appealing to make the dining experience pleasant.

Sustainability: If possible, materials that are sustainable or recyclable would be ideal, aligning with the increasing focus on eco-friendly technologies in space exploration.

In essence, the geometric study and material selection are about finding the perfect balance between form and function, ensuring the dining table is practical, safe, and enjoyable to use in a zero-gravity environment. This process involves careful consideration of the unique conditions of space, the specific needs of astronauts, and the integration of VR technology, all while keeping in mind the limitations and opportunities of space travel.

Keeping that in mind Titanium and High-Grade Carbon Fiber and PEEK are the two-right choices. Luckily PEEK and Carbon Fiber can be combined which is called Carbon PEEK

Let's have a comparison of the two materials in this context:

When considering materials for a dining table in a space station, comparing Carbon PEEK (Polyether Ether Ketone) with Titanium involves several factors:

1. Strength and Weight:
   - Carbon PEEK: Offers a high strength-to-weight ratio, crucial in space where reducing weight is essential.
   - Titanium: Also known for a high strength-to-weight ratio, though it tends to be heavier than Carbon PEEK for equivalent strength.

2. Temperature Resistance:
   - Carbon PEEK: Exceptionally high temperature resistance, maintaining stability and mechanical properties over a wide temperature range.
   - Titanium: Very good temperature resistance, but it may not match the upper limits of Carbon PEEK.

3. Durability and Resistance:
   - Carbon PEEK: Highly durable with excellent wear, chemical, and impact resistance, beneficial in the challenging environment of a space station.
   - Titanium: Extremely durable and resistant to corrosion, but might be more susceptible to scratching compared to Carbon PEEK.

4. Fabrication and Repair:
   - Carbon PEEK: Easier to machine and fabricate than traditional composites; can be more readily repaired or modified.
   - Titanium: Requires conventional metalworking techniques (machining, welding); repairing it might be more complex than Carbon PEEK.

5. Cost:
   - Carbon PEEK: Generally, more expensive due to its advanced properties and the cost of PEEK polymer.
   - Titanium: Expensive, but usually less costly than Carbon PEEK.

6. Safety and Suitability for Space:
   - Both materials: Suitable for space applications, but specific testing for outgassing and toxicity is necessary to ensure they meet space safety standards.

7. Aesthetic and Design Flexibility:
   - Carbon PEEK: Offers the potential for more complex shapes and designs due to its moldability.
   - Titanium: While versatile in design, it may not offer the same level of design flexibility as Carbon PEEK.

In summary, for a space station dining table, Carbon PEEK presents advantages in weight, temperature resistance, durability, and ease of fabrication, making it well-suited for the space environment. Titanium, while also strong and durable, might be heavier and less flexible in terms of design compared to Carbon PEEK. The choice between them would depend on the specific priorities of the mission, such as weight constraints, budget, and desired table features.

In future when space travel was frequent, we need to understand the cost of sending things up. Things that are cheaper and lighter should be preferred.

Let's take a look at Cost per KG for Carbon PEEK and Titanium.
Carbon Peek: €100 to €200 per kilogram
Titanium: €20 to €40 per kilogram

To calculate the cost per cubic centimeter (cc) for both Carbon PEEK and Titanium, we'll need to use their respective densities along with the per kilogram cost estimates I provided earlier. Let's do the math:

1. Carbon PEEK:
- Density: Approximately 1.3 to 1.45 g/cm³ (this can vary slightly based on the specific type of Carbon PEEK).
- Cost per Kilogram: Assume an average cost of €150 per kilogram (as Carbon PEEK can range from €100 to €200 per kg).
- Conversion: There are 1,000 cubic centimeters in a liter, and 1 liter of water weighs approximately 1 kilogram. Thus, for a density of 1.3 to 1.45 g/cm³, 1 cc of Carbon PEEK weighs 1.3 to 1.45 grams.

2. Titanium:
- Density: Approximately 4.5 g/cm³.
- Cost per Kilogram: Assume an average cost of €30 per kilogram (as Titanium can range from €20 to €40 per kg).
- Conversion: With a density of 4.5 g/cm³, 1 cc of Titanium weighs 4.5 grams.

Now, let's calculate the cost per cubic centimeter for both materials.

Based on the calculations:

1. Carbon PEEK: The cost per cubic centimeter is approximately €0.115 (or 11.5 euro cents).
2. Titanium: The cost per cubic centimeter is approximately €0.0067 (or 0.67 euro cents).

This means that on a per cubic centimeter basis, Carbon PEEK is significantly more expensive than Titanium. The high cost of Carbon PEEK is reflective of its advanced properties and specialized applications.
BUT THERE IS MORE!!

Even though titanium is cheaper we should know how much will it cost to send a Dining Table Made of Titanium vs How much it will cost to send a dining table made of Carbon PEEK.

To estimate the cost of sending a table made of either Carbon PEEK or Titanium into space, we need to consider the mass of the table and the cost of sending payload into space. Let's assume the table has a volume of 1 cubic meter (1,000,000 cubic centimeters) for simplicity:

1. Calculating the Mass:
- Carbon PEEK Table: With a density of about 1.3 g/cm³, the mass of a 1 cubic meter table would be 1,300,000 grams (1,300 kg).
- Titanium Table: With a density of about 4.5 g/cm³, the mass of a 1 cubic meter table would be 4,500,000 grams (4,500 kg).

2. Cost of Sending Payload to Space:
- The cost to send a kilogram into space varies but let's use an approximate figure of €20,000 per kg. This is a rough estimate and the actual cost can be significantly higher or lower depending on the space agency, launch vehicle, and other factors.

vNow, let's calculate the cost of sending each table into space.

Based on the calculations:

1. Carbon PEEK Table:
   - Mass: 1,300 kg
   - Cost to Send into Space: €26,000,000

2. Titanium Table:
   - Mass: 4,500 kg
   - Cost to Send into Space: €90,000,000

This demonstrates that while Carbon PEEK is more expensive per unit weight, the overall cost of sending a Carbon PEEK table into space is significantly lower than that of a Titanium table due to the substantial difference in weight. The lighter weight of Carbon PEEK results in a much lower cost for space transport despite its higher material cost.

So when making a cost-effective table we should not only think about how much it costs on earth but also when we send it to space. To give a better example to send the same table to space made of aluminum it would cost €54,000,000 and a wood will be €15,000,000.

3.3 Technological Considerations

When designing a zero-gravity dining table integrated with Virtual Reality (VR), there are several technological considerations to account for. These considerations ensure that the table not only functions well in a zero-gravity environment but also effectively incorporates VR technology. Let's break down what these considerations might include:

1. Durability and Safety

Space-Safe Materials: The technology used should be durable and safe for space environments. This means materials and electronics that can withstand microgravity, exposure to space radiation, and the closed environment of a space station.

Reduced Risk of Damage: Given the challenges of repairing or replacing equipment in space, the technology should be robust and have a low risk of malfunctioning.

2. Compatibility with Spacecraft Systems

Spacecraft Integration: The table must be compatible with the existing systems on the spacecraft. This includes physical integration (size and fit) and technical compatibility (such as connecting to the spacecraft's power and data systems).

3. Maintenance and Upgradability

Ease of Maintenance: Given the complexity of conducting repairs in space, the system should be easy to maintain.

3.4 Virtual Simulations and Prototypes

Let's talk about how I will go through the virtual simulation for the existing design to taking survey then Virtual Simulation of New Design based on surveys and prototypes

Virtual Simulations

By using a pre-existing game called Mission ISS I will try to gather some general opinions from different people from different backgrounds. This will help in understanding the general opinion for a preexisting design. Based on that we will generate a form for the table. We will take the good part from the table and use it. We will also try to understand the movement around it and how we can improve the overall experience around it. The VR will help a lot in understanding this.

Testing in Virtual Space: The main advantage of this simulations is that I can test how my design performs in a virtual zero-gravity setting. You can see how astronauts might interact with the table, how they access food, and how they use VR without leaving Earth.

Adjusting Designs: Based on these tests, I can make adjustments to my design. For example, I might change the table's shape or size, or tweak how the VR system integrates with the table, all within the virtual model.

Safety and Usability: Simulations also allow you to assess the safety and usability of your design. This is crucial in ensuring that the final product will be both practical and comfortable for astronauts to use.

3.5 Open Points and Limitations in Current Research

Open Points in Research

Psychological Impact: The long-term psychological effects of zero-gravity dining combined with VR are not fully understood.

Limitations in Current Research

VR Technology Constraints: Current VR technologies may have limitations in resolution and immersive capabilities that are crucial for a fully engaging dining experience.

Material and Design Challenges: Ideal materials and designs for a zero-gravity environment might be hard to implement due to availability or cost issues.

Data Availability: There's a lack of extensive research specifically focused on zero-gravity dining, limiting the ability to base designs on existing data.

Testing Limitations: Accurately replicating a zero-gravity environment for thorough testing on Earth is challenging.

Addressing Limitations

Recognizing these limitations is a critical part of the research process. It shows an understanding of the project's complexities.

Identifying these areas provides a foundation for future research, guiding others in the field to address these gaps and advance the knowledge in zero-gravity dining and VR.

Conclusion

Acknowledging and exploring these open points and limitations are essential for advancing the field. While there are challenges, these also present opportunities for innovation and future research, contributing to the ongoing development of space habitation technologies, particularly in enhancing the dining experience with VR in zero-gravity conditions.

3.6 Market Limitations and Opportunities for Innovation

In the realm of zero-gravity dining and Virtual Reality (VR) integration, analyzing "Market Limitations and Opportunities for Innovation" is a key aspect. This process involves examining the current market to understand its constraints and identifying where new, innovative ideas could make a significant impact. Let's break down what this means in simple terms:

Market Limitations

Limited Consumer Base: The primary market for zero-gravity dining solutions is quite niche, largely limited to astronauts and space agencies. This small consumer base can limit the financial incentive for companies to invest in developing new products.

High Costs: Space technology, including anything designed for zero gravity, typically involves high production and research costs. These expenses can be a significant barrier to entry for many companies.

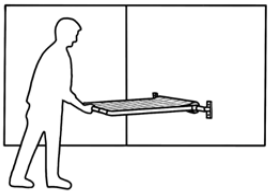
Safety and Compliance: Products designed for space must meet stringent safety and compliance standards. These requirements can be challenging to fulfill, adding complexity and cost to product development.

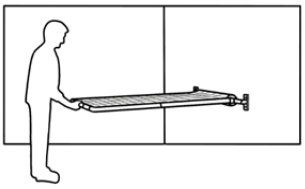
Logistical Challenges: Getting products to space is a logistical challenge. Size, weight, and durability are critical factors, as is the ability to function correctly in a zero-gravity environment. We never got our hands on the dining table and just experienced in VR. This makes it a little difficult to understanding the little things on which we can work on. The best way to overcome these issues is to look at countless astronaut interviews available online and get the important things out of it.

For example, they do not cut the MRE food packets all the way through because that would lead to extra small waste.

An alternative design proposed includes using an elastic net as a tabletop, which would reduce the weight and allow users to secure loose objects in the grid. This design could declutter the space and minimize the need for tape and Velcro. [https://irisyaao.com/nasa]

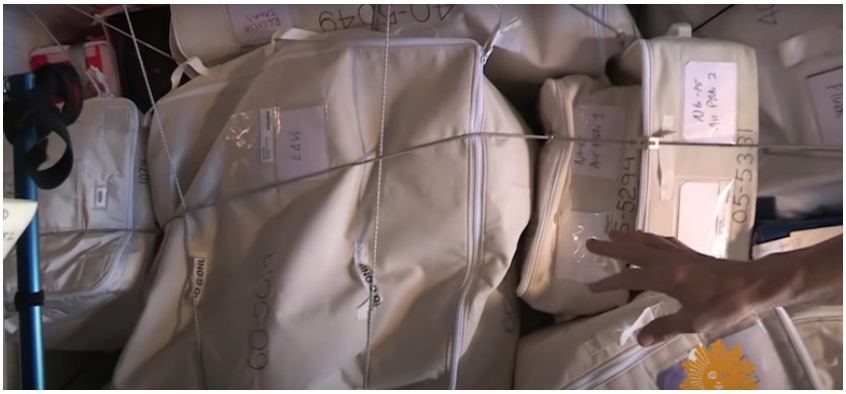
Another improvement could involve making the table configurable in size, allowing astronauts to extend the table single-handedly. This could provide more flexibility and adaptability to the varying needs of the crew. [https://irisyaao.com/nasa]



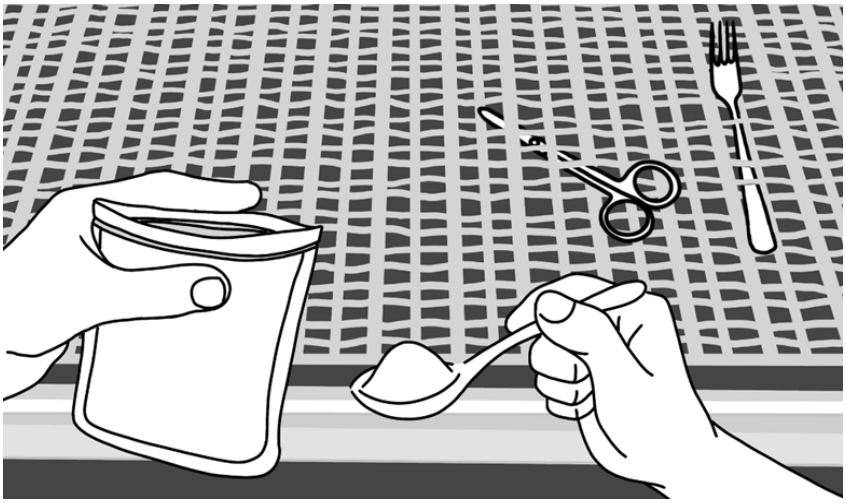


But this creates a problem that is in space your mass is zero so how you are going to pull this thing out? You will just pull yourself closer to the table instead of extending the table and bringing it closer to you. So initially when I talked about how the design can not be done in isolation I meant this.

To explain it better here is a picture of the new resistive exercise device in Mengtian Laboratory Module of Chinese Space Station which is a rowing machine used by Astronaut LIU Yang. You will notice how the astronaut have to tie herself to the chair in order to pull the handle.



And when it comes to the net mesh, it has been used widely across the space station and works well, but omitting the Velcro is not a good idea as it is lightweight, easy to install and easy to use. The maintenance is low and can be swapped. So, the Velcro is a good idea as it is everywhere from different places of space station to the suits and clothes of Astronauts.



Overall, the design of the dining table in the ISS reflects the unique challenges of living and working in space. While it successfully addresses some of these challenges, there is room for improvement, especially in terms of human-centric design and fostering a sense of community among the crew.

Opportunities for Innovation

Niche Market Advantage: The niche nature of the market means that specialized products can be highly valued. Innovative designs that significantly improve astronauts' dining experiences can gain quick recognition and adoption.

Cross-Industry Applications: Technologies developed for space can often be adapted for use in other industries. For instance, a dining table designed for zero gravity could have applications in medical or aviation industries.

Partnerships and Collaboration: Collaborating with space agencies, research institutions, and other technology companies can open up opportunities for innovation. These partnerships can provide the necessary resources and expertise to tackle complex challenges.

Educational and Entertainment Value: Beyond practicality, there's potential for educational and entertainment applications. For example, using VR with zero gravity simulation for astronaut training (as mentioned before).

Sustainability and Efficiency: Innovations that focus on sustainability, such as using recyclable materials or energy-efficient designs, can meet a growing demand for eco-friendly solutions.

In conclusion, while there are certain limitations in the market for zero-gravity dining and VR, these constraints also open doors for innovative solutions. By addressing specific challenges unique to space dining, there's potential to not only enhance the astronaut's experience but also to develop technologies that could have broader applications on Earth. Understanding these market dynamics is crucial for guiding research and development in a direction that is not only technologically feasible but also commercially viable and beneficial.

PART TWO
DESIGN

Designing the VR based dining table for zero gravity

4. Questionnaires and Surveys

4.1 Design and Purpose of Questionnaires

Sample Size - 40

The role of this chapter is to analyze and understand different opinions of different people when it comes to preexisting design of the space station. I used Mission ISS for Oculus for the zero G simulation in VR and took survey of people who experienced it through VR.

General Experience:

After experiencing the space station's dining area through VR, how intuitive did you find the layout of the dining table?

- ☐ Very unintuitive
- ☐ Somewhat Unintuitive
- ☐ Neutral
- ☐ Somewhat intuitive
- ☐ Very intuitive

Were you able to comfortably navigate around the dining table area in the VR environment?

- ☐ Very uncomfortably
- ☐ Somewhat uncomfortably
- ☐ Neutral
- ☐ Comfortably
- ☐ Yes, very comfortably

Comfort and Ergonomics:

How comfortable did the seating/standing/floating arrangements at the dining table appear to you?

- ☐ Very uncomfortable
- ☐ Somewhat uncomfortablev
- ☐ Neutral
- ☐ Somewhat comfortable
- ☐ Very comfortable

Based on your VR experience, how would you rate the ergonomics of the dining table area?

- ☐ Very Poorv
- ☐ Poor
- ☐ Neutral
- ☐ Good
- ☐ Excellent

Functionality:

Did the dining table provide adequate space for meals and other activities based on your observation?

- ☐ No, never
- ☐ Somewhat never
- ☐ Neutral
- ☐ Somewhat alwaysv
- ☐ Yes, always

Based on your VR observation, how effective do you think the dining table is in containing spills and managing crumbs in a zero-gravity environment?

- ☐ Very ineffective v
- ☐ Ineffective
- ☐ Neutral
- ☐ Effective
- ☐ Very effective

Design and Aesthetics:

How visually appealing did you find the design of the dining table in the VR environment?

- ☐ Very unappealing
- ☐ Unappealing
- ☐ Neutral
- ☐ Appealing
- ☐ Very appealing

Did the design of the dining table blend well with the overall interior of the space station in the VR environment?

- ☐ Very unintuitive
- ☐ Somewhat not well
- ☐ Neutral
- ☐ Somewhat well
- ☐ Yes, very well

Improvements:

What feature(s) would you like to see improved or added to the dining table?

Your answer

Would you prefer a dining table with integrated technology (e.g., touch screens, charging ports) as observed in VR?

- ☐ Definitely not
- ☐ No
- ☐ Neutral
- ☐ Definitely
- ☐ Yes, definitely

Safety:

Based on your VR experience, how safe did you feel while exploring the dining table area in a zero-gravity environment?

- ☐ Very unsafe
- ☐ Unsafe
- ☐ Neutral
- ☐ Safe
- ☐ Very safe

Did you notice any potential safety hazards around the dining table area in the VR environment?

- ☐ No
- ☐ Yes

Accessibility:

How easily could you access the dining table and seating in the VR environment?

- ☐ Very difficultly
- ☐ Difficultly
- ☐ Neutral
- ☐ Somewhat easily
- ☐ Very easily

Was the dining area easily distinguishable from other areas in the VR space station environment?

- ☐ Very indistinguishable
- ☐ Indistinguishable
- ☐ Neutral
- ☐ Distinguishable
- ☐ Yes, very distinguishable

Storage and Cleaning:

Did you notice any storage solutions near or within the dining table area in the VR environment?

- ☐ No
- ☐ Yes

Based on your VR experience, how would you rate the ease of cleaning for the dining table area?

- ☐ Very Poor
- ☐ Poor
- ☐ Average
- ☐ Good
- ☐ Excellent

Interaction and Social Experience:

Did the dining table area seem conducive to social interaction among crew members?

- ☐ Very unconducive
- ☐ Somewhat unconducive
- ☐ Neutral
- ☐ Somewhat conducive
- ☐ Yes, very conducive

Was there sufficient lighting in the dining table area to comfortably eat and interact with others?

- ☐ Very insufficient
- ☐ Somewhat insufficient
- ☐ Neutral
- ☐ Somewhat sufficient
- ☐ Yes, very sufficient

Technology and Innovation:

Did you observe any innovative features in the dining table area that enhance usability or experience?

- ☐ No
- ☐ Yes

Would you appreciate having interactive displays or other technological enhancements in the dining table area?

- ☐ Definitely not
- ☐ Yes, definitely

4.2 Administration and Response Collection

These are responses I got from the 40 people

General Experience:
1. Intuitiveness of Layout - 1.68/5
2. Navigation Comfort - 1.60/5

Comfort and Ergonomics
1. Seating Arrangements - 1.60/5
2. Ergonomics Rating - 1.85/5

Functionality
1. Space Adequacy -1.95/5
2. Spill Management - 2.05/5

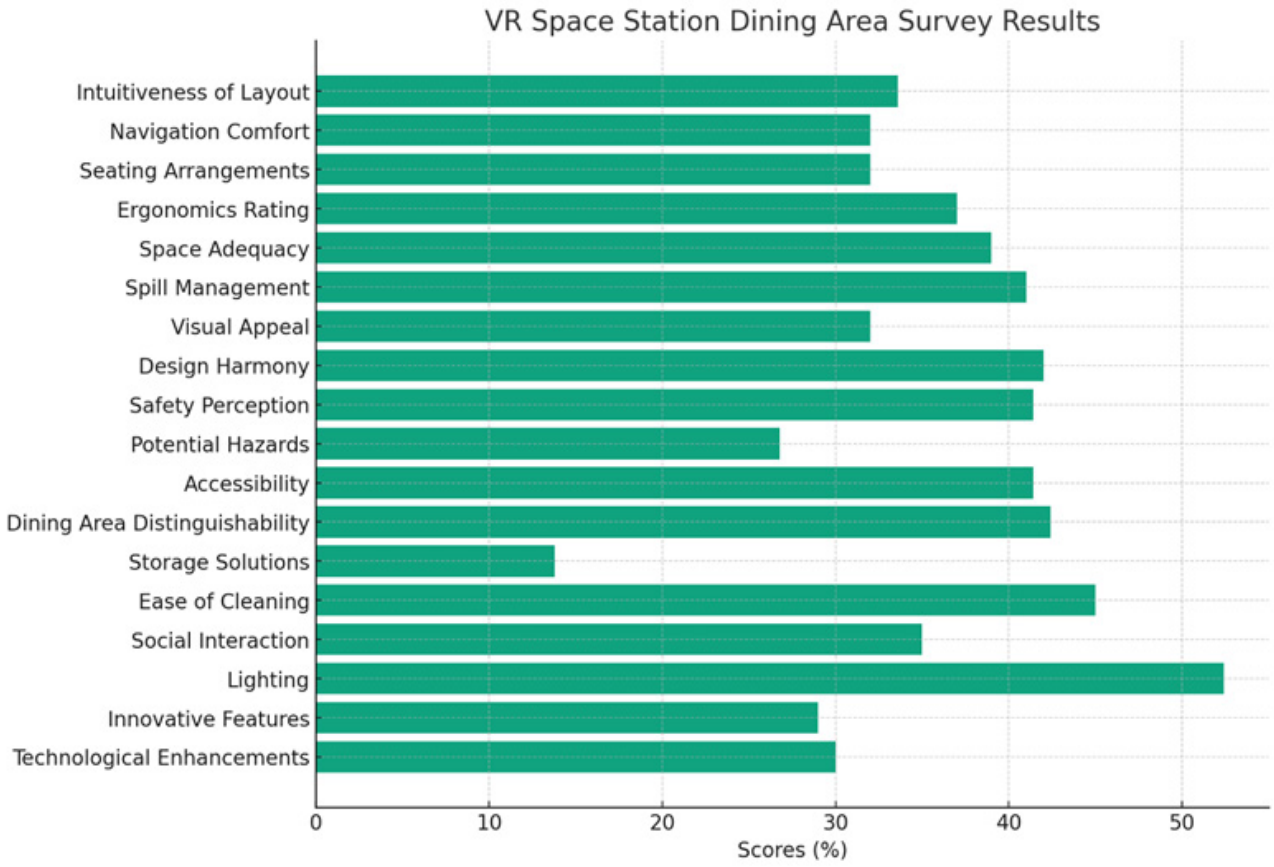
Design and Aesthetics
1. Visual Appeal - 1.60/5
2. Design Harmony - 2.10/5

Safety and Accessibility
1. Safety Perception - 2.07/5
2. Potential Hazards - 1.34/2
3. Accessibility - 2.07/5
4. Dining Area Distinguishability - 2.12/5

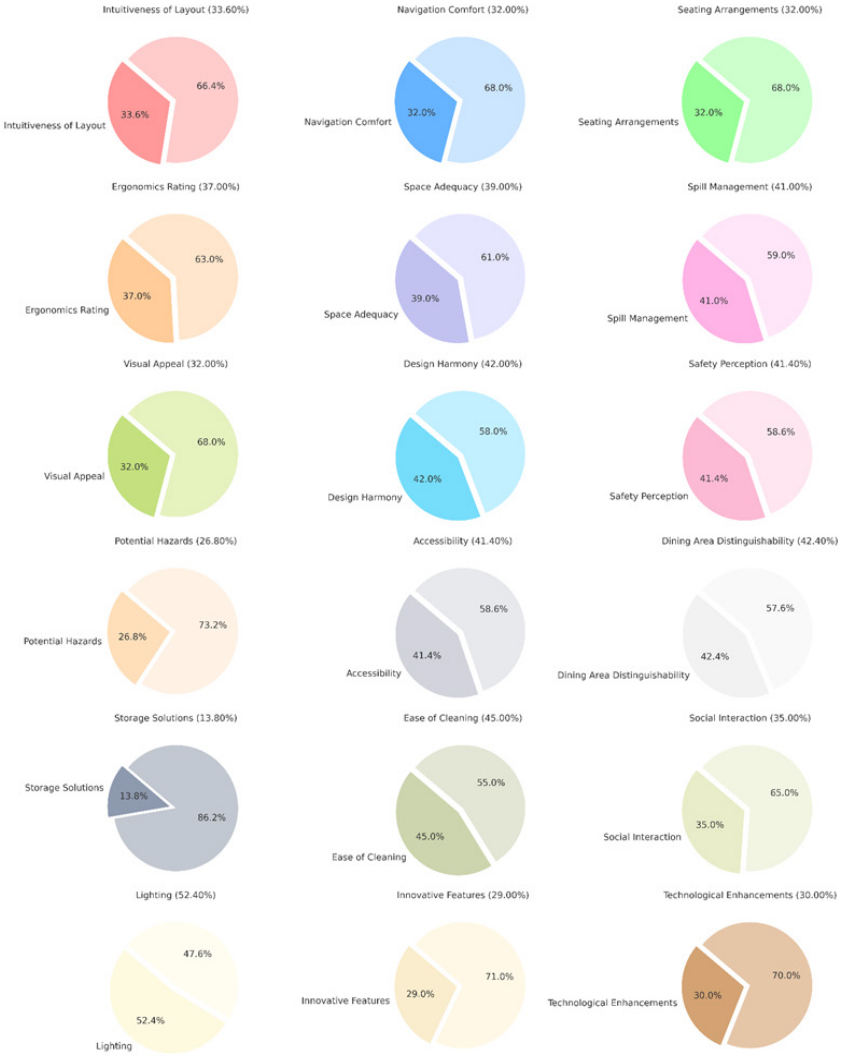
Storage and Cleaning
1. Storage Solutions - 0.69/2
2. Ease of Cleaning - 2.25/5

Interaction and Social Experience
1. Social Interaction - 1.75/5
2. Lighting - 2.62/5

Technology and Innovation
1. Innovative Features - 1.45/2
2. Technological Enhancements - 1.50/2



4.3 Data Analysis and Interpretation



General Experience:

1. Intuitiveness of Layout (Average: 1.68/5): The moderate score suggests that users found the layout somewhat intuitive but with noticeable room for improvement. The layout could be streamlined or simplified to enhance user experience.
2. Navigation Comfort (Average: 1.60/5): This score indicates that users experienced some difficulty in moving around the dining area. Improvements could include clearer signage, better spatial planning, or interactive guides.

Comfort and Ergonomics:

1. Seating Arrangements (Average: 1.60/5): The average comfort level suggests the need for more ergonomic design in seating arrangements. Consideration could be given to adjustable and versatile seating that accommodates various postures and activities.
2. Ergonomics Rating (Average: 1.85/5): While slightly better, this still indicates a need for improvement. Focusing on ergonomic principles such as ease of reach, proper height adjustments, and comfort can enhance the overall user experience.

Functionality:

1. Space Adequacy (Average: 1.95/5): The score reflects a modest satisfaction with the space provided. It suggests that users might find the area cramped or poorly organized. Redesigning for more efficient use of space or better zoning could address this.
2. Spill Management (Average: 2.05/5): A fairly positive response indicates that the current measures for spill management are adequate, yet there's still scope for innovative solutions, especially considering the unique challenges of a zero-gravity environment.

Design and Aesthetics:

1. Visual Appeal (Average: 1.60/5): This score reflects an average perception of the dining area's visual design. Enhancements could include more visually appealing materials, colors, and lighting to create a more inviting atmosphere.

2. Design Harmony (Average: 2.10/5): While the dining area somewhat blends with the overall interior, there's potential for better integration. Consistency in design elements or themes can improve the sense of harmony.

Safety and Accessibility:

1. Safety Perception (Average: 2.07/5): The moderate safety score suggests users feel relatively safe but highlights the need for improvements, perhaps in terms of better emergency protocols or safer furniture designs.
2. Potential Hazards (Average: 1.34/2): The score indicates few noticed hazards, but continuous evaluation of safety aspects remains essential.
3. Accessibility (Average: 2.07/5): This score suggests some difficulties in accessing the dining area. Improvements could include clearer pathways, better signage, and accommodating different mobility needs.
4. Dining Area Distinguishability (Average: 2.12/5): The area is somewhat distinguishable, but could benefit from unique design features or thematic elements to stand out more clearly.

Storage and Cleaning:

1. Storage Solutions (Average: 0.69/2): The positive response here indicates that storage solutions are well-implemented. Continuing to provide ample and intuitive storage options is key.
2. Ease of Cleaning (Average: 2.25/5): While not poor, this suggests that cleaning procedures could be streamlined or that materials and surfaces could be chosen for easier maintenance.

Interaction and Social Experience:

1. Social Interaction (Average: 1.75/5): The average score here suggests the design is moderately conducive to social interaction. Enhancing this could involve creating more communal spaces or interactive features that encourage communication.
2. Lighting (Average: 2.62/5): The relatively positive score for lighting suggests that the current setup is adequate for visibility and comfort, though there might be room for minor improvements.

Technology and Innovation:

1. Innovative Features (Average: 1.45/2): This high score indicates that the innovative features present are well-received and appreciated. Continued emphasis on incorporating cutting-edge technology can enhance the user experience further.
2. Technological Enhancements (Average: 1.50/2): The strong preference for technological enhancements suggests a significant interest in interactive and high-tech features. This could include smart tables, interactive menus, or augmented reality elements.

Other than survey here are some opinions from professionals who work in space industry

Microgravity Challenges:

In microgravity, everyday activities like eating take on a different dimension:

1. Food Management: Without gravity, food doesn't stay put on plates. Instead, astronauts use specially designed containers to hold their food. These containers are often similar to military MREs (Meals, Ready-to-Eat) or camping food packets.
2. Utensils: Magnetic cutlery is used to prevent it from floating away. Utensils typically have Velcro on them so they can be stuck to the walls when not in use.
3. Drinking Liquids: Liquids in space are a particular challenge. In microgravity, they form floating blobs that can be messy and dangerous if they get into equipment. Hence, astronauts drink liquids from special sealed pouches with straws. These pouches are designed to prevent the liquid from floating away and allow astronauts to suck the liquid out.

Social Aspect:

Mealtimes on the ISS are more than just a necessity; they are a crucial part of the astronauts' daily routine:

1. Bonding Time: Meal times are a communal event, offering a chance for astronauts to gather and bond. Given the isolation and intensity of space missions, these moments are essential for morale.
2. Cultural Exchange: Astronauts often enjoy foods from different countries, reflecting the international nature of the ISS crew. Sharing food becomes a way of sharing culture and building camaraderie.

Social Aspect:

Constraints and Innovations

The dining area in the ISS is a marvel of efficient space use and innovative design:

1. Space Utilization: The dining area is compact, reflecting the premium on space in the ISS. Every inch is carefully designed to maximize utility.
2. Use of Velcro and Magnets: To manage the challenges of microgravity, the walls in the ISS, including in the dining area, are lined with Velcro. Astronauts use this to secure themselves, their food packets, and utensils. Magnets are also used for securing metal objects.
3. Meal Preparation and Storage: Meals are typically prepared by adding water to freeze-dried foods. Cold storage is limited, so most food is stored at room temperature.

Overall Considerations:

Enhance User Experience: To focus on making the dining area more intuitive and comfortable to navigate.

Prioritize Ergonomics and Comfort: Improving seating and overall ergonomics can significantly enhance comfort.

Space Optimization: Efficient use of space and innovative spill management solutions are crucial.

Design Improvements: Enhancing the visual appeal and ensuring design harmony with the station's interior can create a more cohesive and pleasant environment.

Safety and Accessibility: Continuously evaluate and improve safety measures and accessibility to ensure inclusivity and security for all users.

Encourage Social Interaction: Design elements that promote socializing can enhance the communal feel of the area.

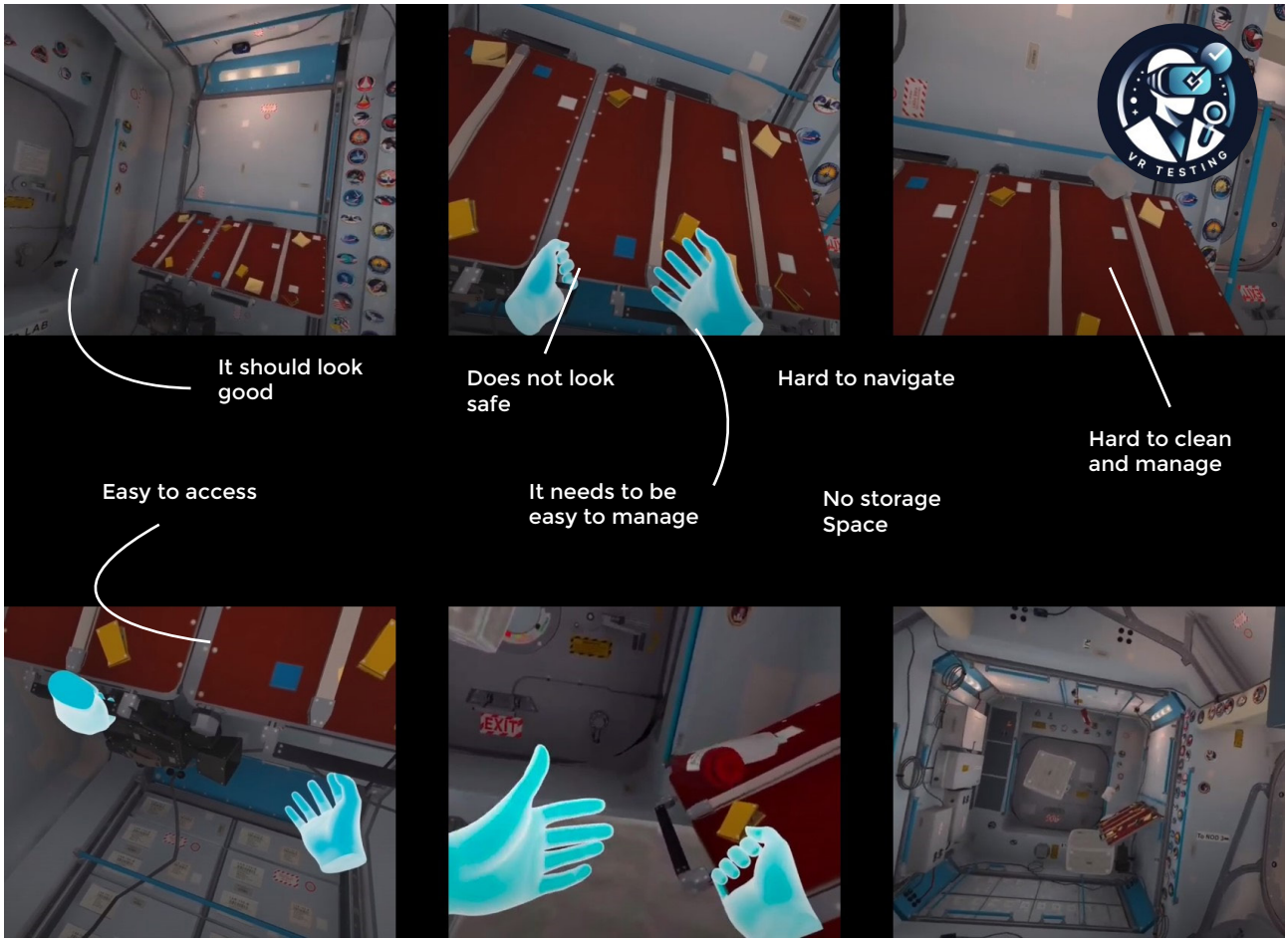
Embrace Technological Advancements: The strong interest in technology suggests that integrating more innovative features could greatly improve the overall dining experience.

So overall the design was not very well liked but people really liked the lighting of the environment. The overall experience and was not well and it did not give enough ample space around it so that people can move across, the current design was not good enough to hold onto it with less space if more people were to join and eat. There was a big safety issue as people did not feel safe moving around it and working around it. The current dining table was not conductive for social interaction The overall general experience was poor and so was the comfort and ergonomics of the table.

5. Ideation

5.1 Needs and Requirements

Let's dive again into the virtual world and see how we can use the VR to understand the problem that we came across and find what are its needs in order to design and better dining table that can work in zero gravity.



Based on the VR experiences our table should be -

5.2 Persona

Name: Commander Rakesh Sharma
Age: 38
Role: ISS Mission Commander
Nationality: Indian

Background:

- A seasoned and highly experienced astronaut with a strong academic and practical background, holding a Ph.D. in Astrophysics.
- Former Air Force pilot, bringing a disciplined and focused approach to his space missions.
- Possesses a wealth of experience from three previous space missions.
- An expert in space station systems, demonstrating deep knowledge and understanding of the intricacies of living and working in space.

Personality Traits:

- Detail-Oriented: Focuses on the minutiae of each task, ensuring everything is done to the highest standard.
- Innovative: Constantly seeking new and efficient solutions to the unique challenges of space living.
- Socially Engaged: Values camaraderie and team cohesion, understanding the importance of morale in the challenging environment of space.
- Efficiency and Safety Focused: Prioritizes efficiency in operations and uncompromising in maintaining safety within the space station.

Needs for Dining in Zero Gravity

1. Functional Dining Solutions:
- Commander Sharma requires dining solutions that effectively cater to the challenges of zero gravity. This means systems that can securely hold food and utensils in place, preventing them from floating away and causing disruptions or potential hazards.

2. Ease of Maintenance and Cleaning:
- The dining area and equipment need to be easy to clean and maintain. In a closed environment like the ISS, it's crucial to avoid loose particles that could harm the equipment or impact the health of the crew.
- Surfaces and materials should be designed to minimize the adherence of particles and be easily wipeable.

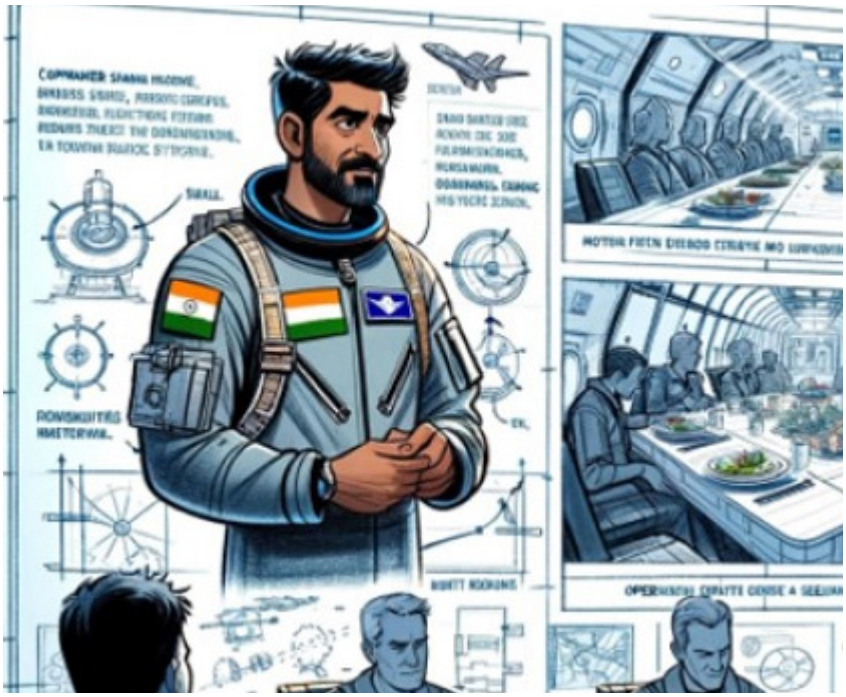
3. A Social and Cohesive Dining Space:
- Recognizing the importance of social interaction, Commander Sharma needs a dining area that not only serves as a place for nourishment but also as a communal space for the crew.
- The design should encourage interaction and serve as a comfortable area for the crew to bond and relax, boosting morale and team cohesion.

Commander Rakesh Sharma's profile as an experienced, detail-oriented, and innovative mission commander informs the specific requirements for a dining setup on the ISS. His background and personality underline the need for a dining solution that is practical in zero gravity, easy to maintain, and conducive to social interaction. The design should integrate efficiency and safety, reflecting his priorities, while also providing a space that strengthens team dynamics and morale.

5.3 Storyboard/User Journey

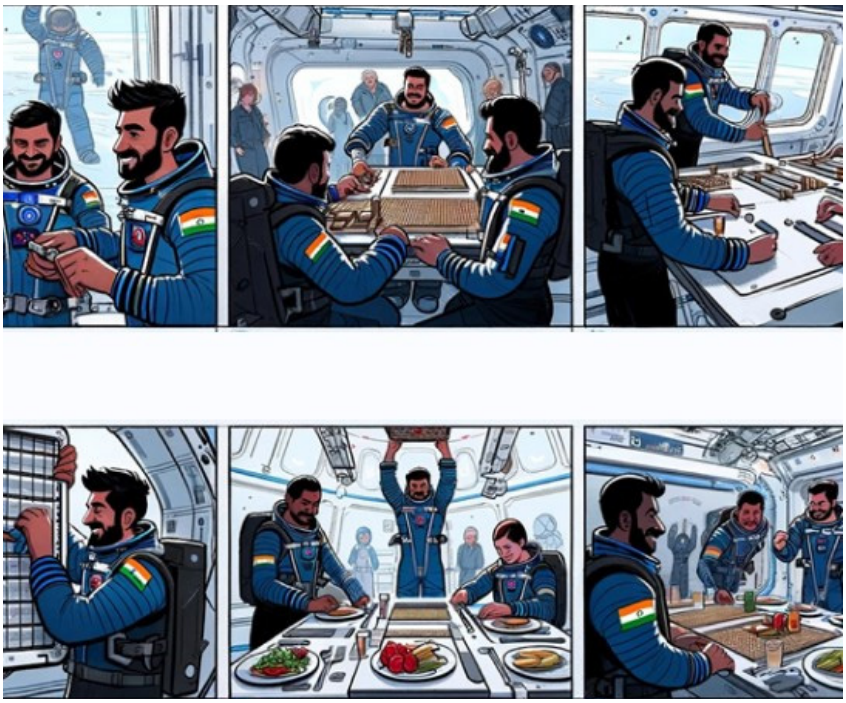
Stage 1:

Encounter Rakesh is introduced to the new zero-gravity dining table during the mission briefing. He reviews the design schematics, safety features, and operational instructions. He is impressed with the thoughtful design that promises a semblance of normalcy during meal times.



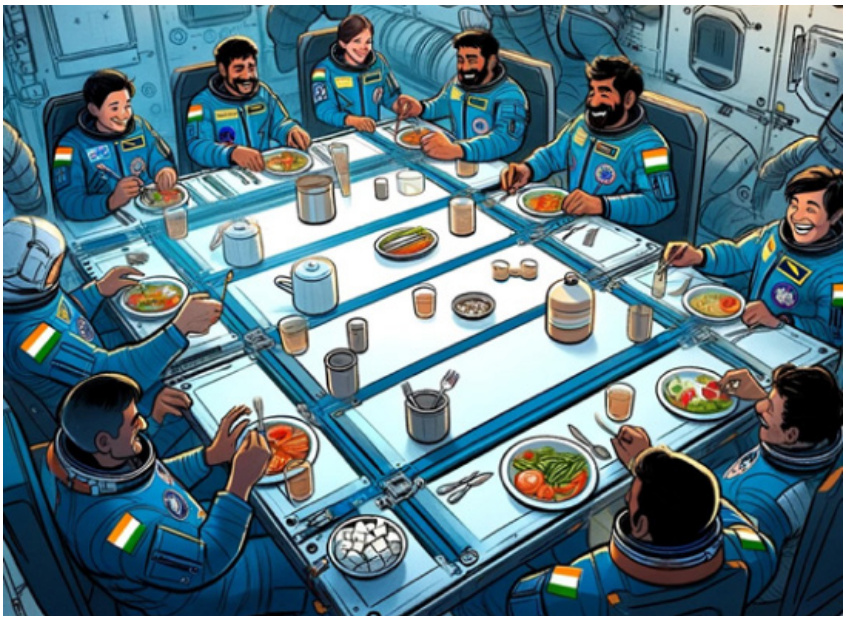
Stage 2:

First Interaction Upon arriving at the ISS, Rakesh and his crew assemble the dining table, which is designed to be lightweight and easy to install. The velcro and mesh net are intuitive, and the crew easily adapts to their new dining setup.



Stage 3:

Routine Use The crew uses the dining table for daily meals. They find that the restraints for utensils and food packets are effective in preventing items from floating away. The table becomes a central point for gathering, discussing mission progress, and sharing personal stories, thus serving both its primary function and enhancing crew morale. The add-ones games which can be fit to the table and many common games which were customized for the zero gravity environment makes the place more fun.



Stage 4:

Maintenance After a few weeks, a minor issue arises with one of the moving parts. Rakesh consults the troubleshooting guide provided with the table and is able to quickly resolve the issue. The easy maintenance design proves to be a significant advantage and because it is not over engineered it can be fixed easily.

Stage 5:

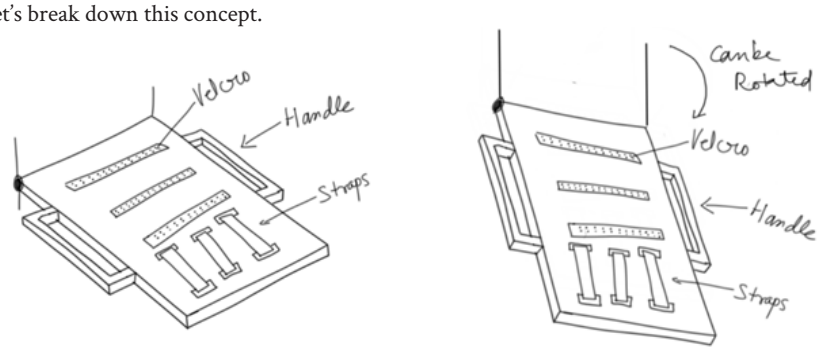
Long-term Adaptation Several months into the mission, the dining table has fully integrated into the crew's life. It has withstood the rigors of daily use and has proven to be a reliable piece of equipment. Rakesh provides feedback to the design team on Earth, suggesting minor improvements for future iterations based on his crew's experience.v

Stage 6:

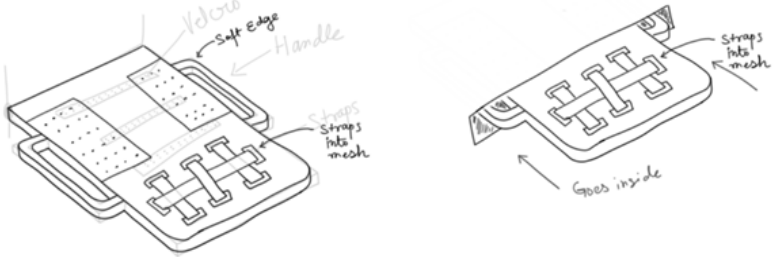
End of Mission As the mission concludes, everyone returned to earth. Rakesh notes its success in his mission report and recommends its continued use on the ISS. The table has not only served its functional purpose but also contributed to the overall well-being of the crew by providing a semblance of normal dining experience in an extraordinary environment. He also mentioned the newly designed socks and spoons which helped in many things.

5.4 Brainstorming / Design form evolutions

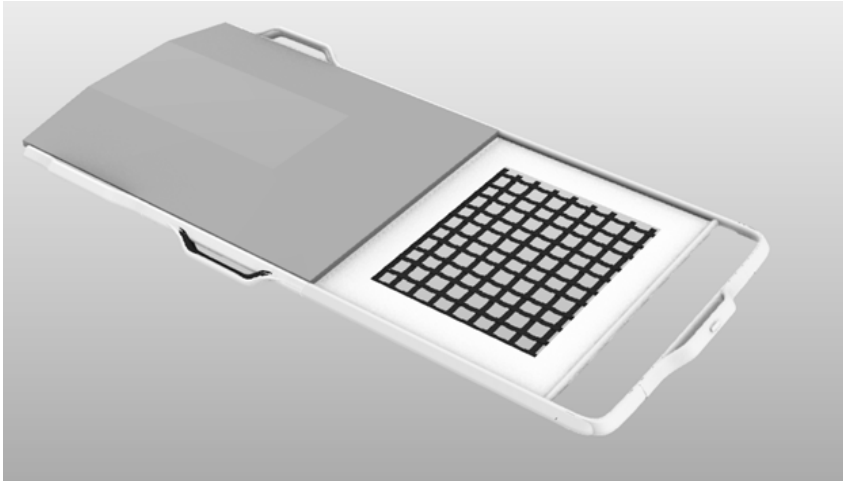
This is a crucial stage in the development of your zero-gravity dining table with Virtual Reality (VR) integration. This process involves generating a wide range of ideas, exploring various design forms, and then evolving these ideas into more refined designs. Let's break down this concept.

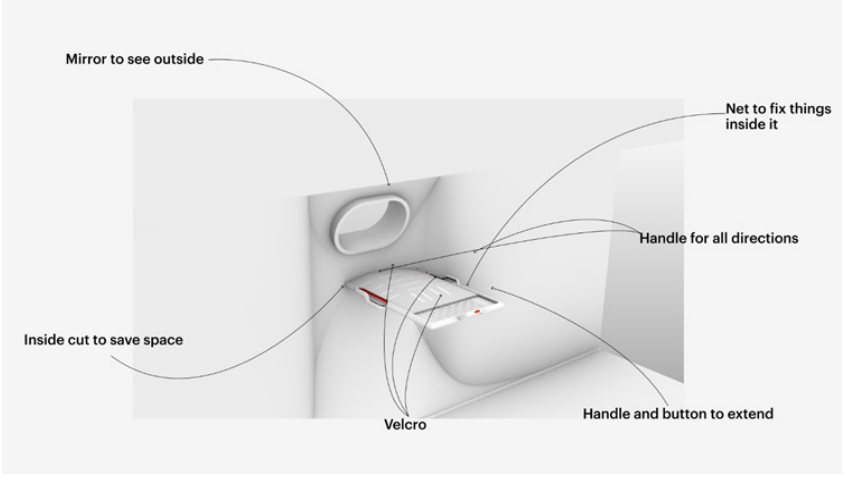


The initial idea was to put handles to the side, make it extendable with option to add some addons to that. Then instead of straps it was better to implement a mesh, the whole table can go inside the wall of space station thus creating more space. Also, the soft edges were introduced for safety.

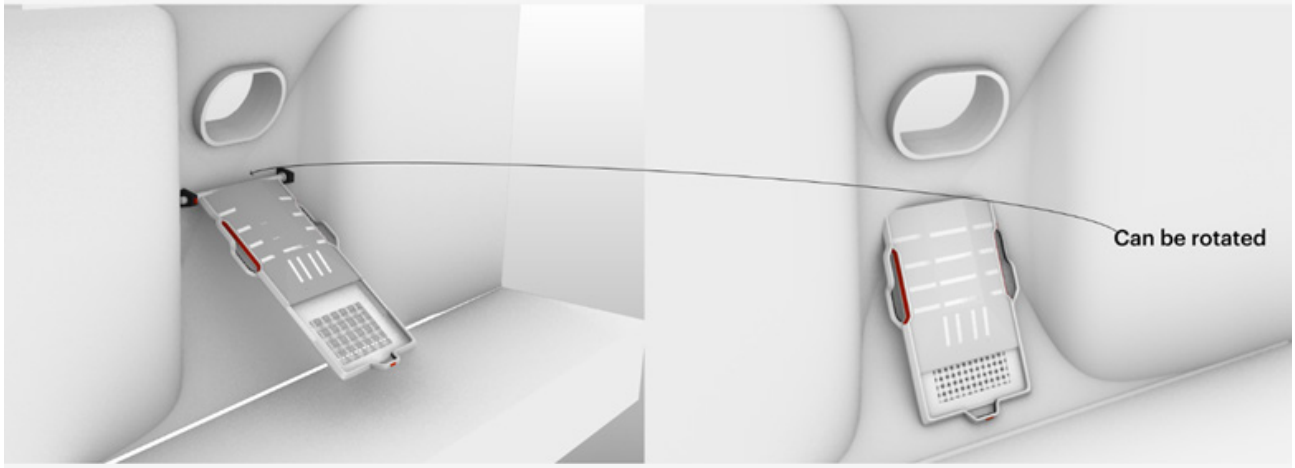


The smaller table was not ideal as less people could able to eat together.



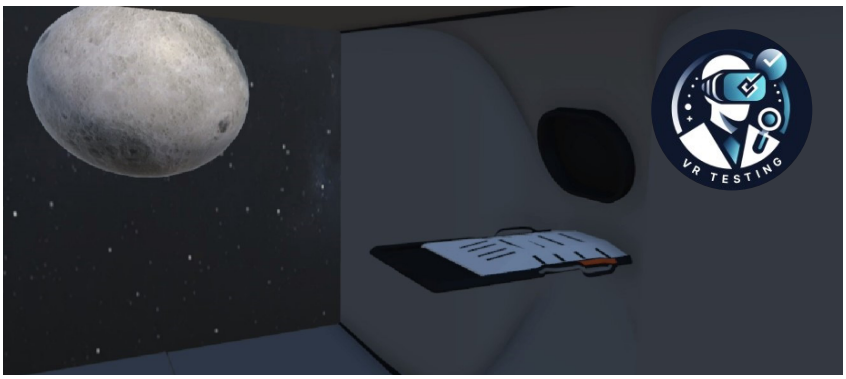

Mirror to see outside
Net to fix things inside it
Handle for all directions
Inside cut to save space
Velcro
Handle and button to extend

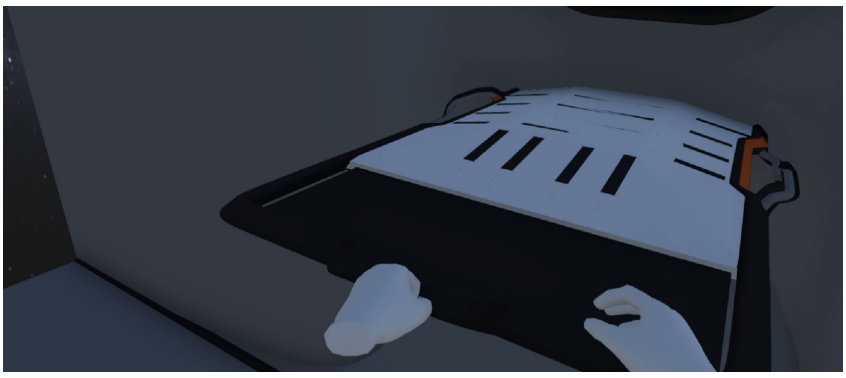
When Rotated

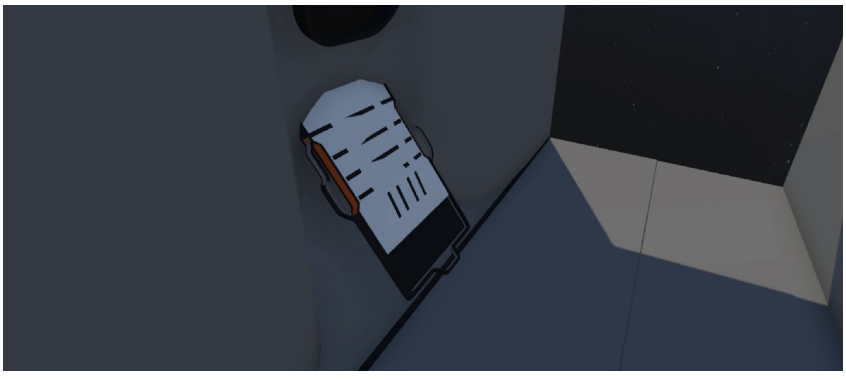


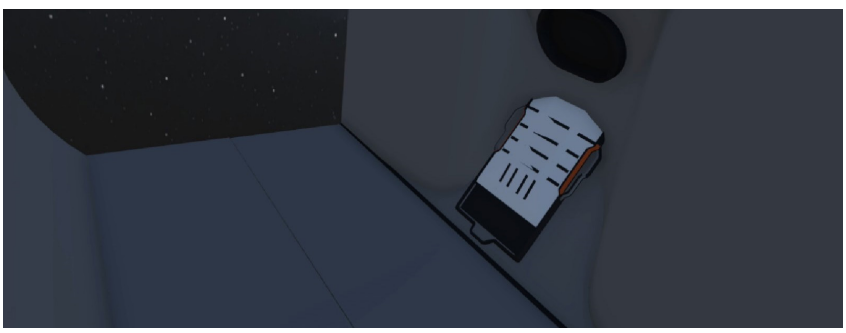
With Add ons

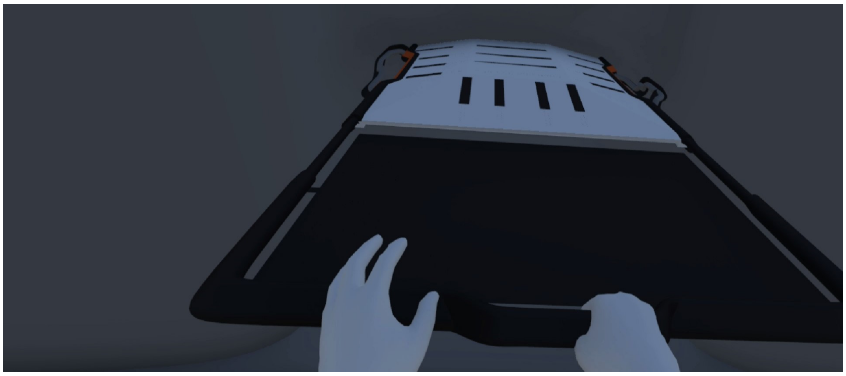
Testing the design in VR:

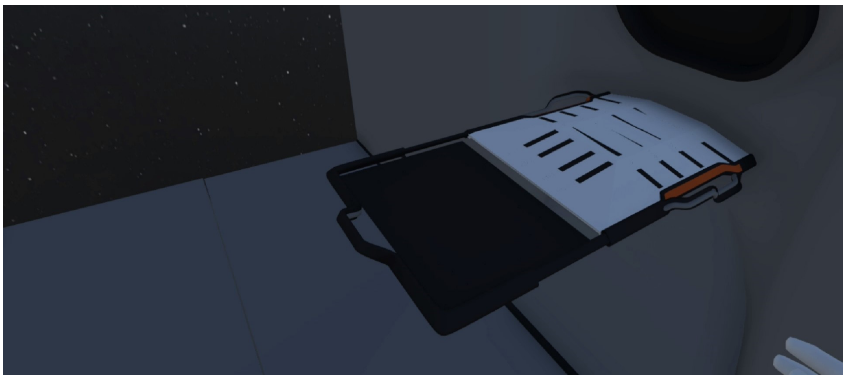




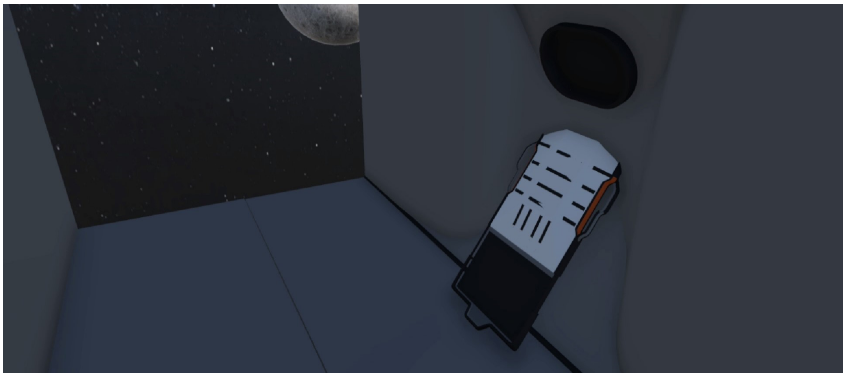




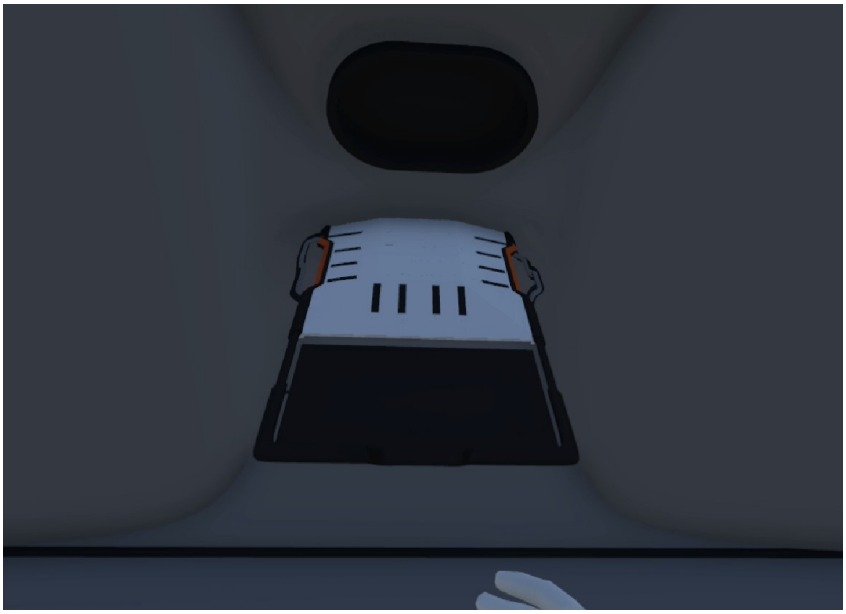




Extended

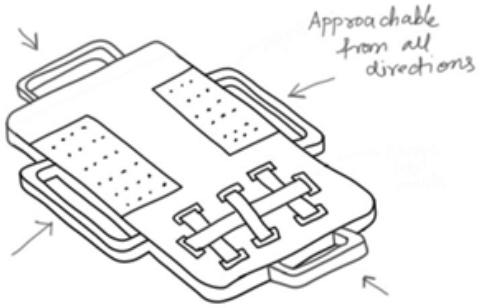


Extended and rotated

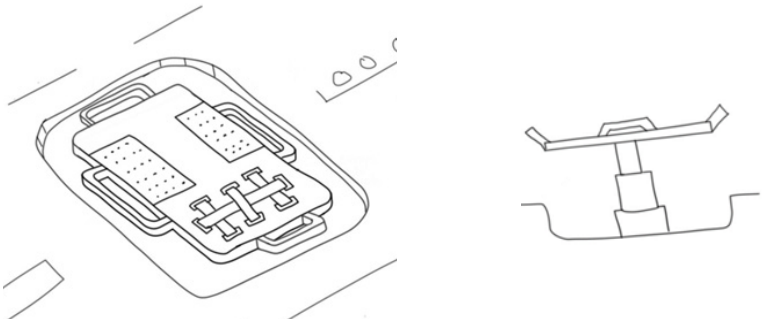


Testing the design in VR helped me understand the problems in the first major design. It was not completely solving anything instead it was just a readjustment. It does solaves the problem of managing spoons and scissors but does not give any manjor storage solution.
Takeaways - Pullout function, Velcro, Rotating table. Handrails.

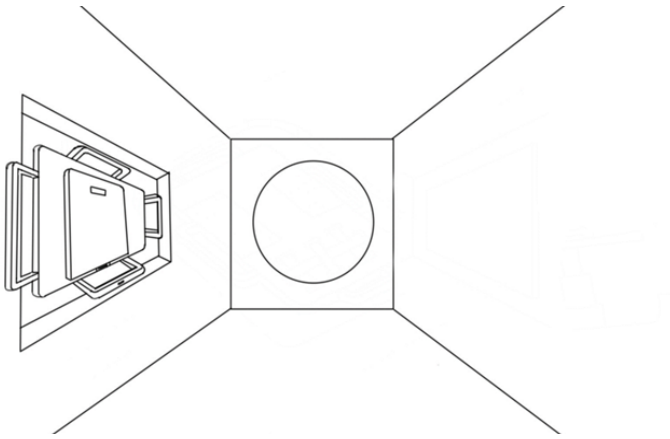
Things to avoild - Space occupying, No railings for legs, not big enough, not different from the original design.



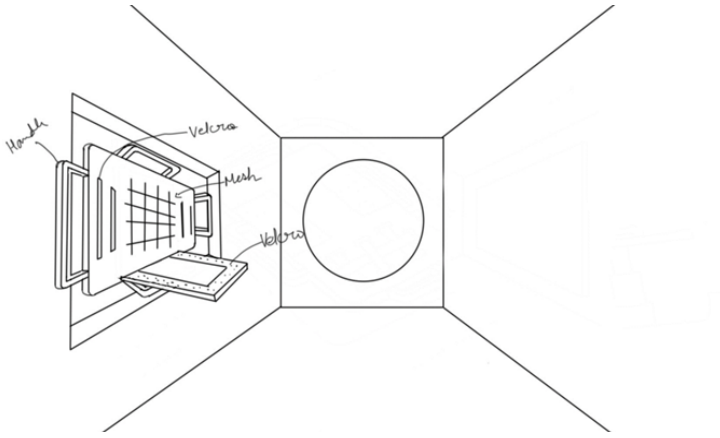
So, a table with soft edges which is approachable from all directions was sketched.



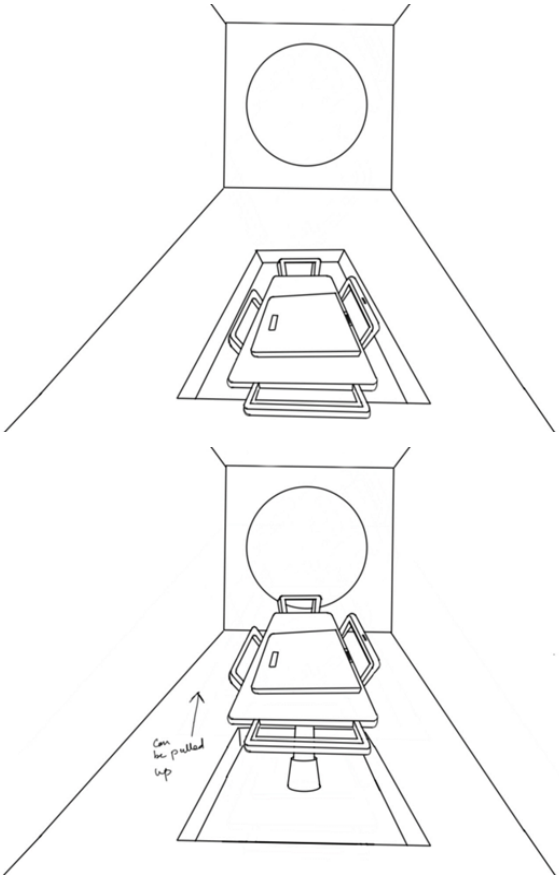
This Table could fit in the wall and still be accessible. The orientation will be different but as we know in space the way we are looking at is the way up. This design will save a lot of space and can be retractable by pulling it out with a press of a button.



This table was bigger but what if a single astronaut wants to use it? added a rotatable smaller table which can be used in a different orientation.

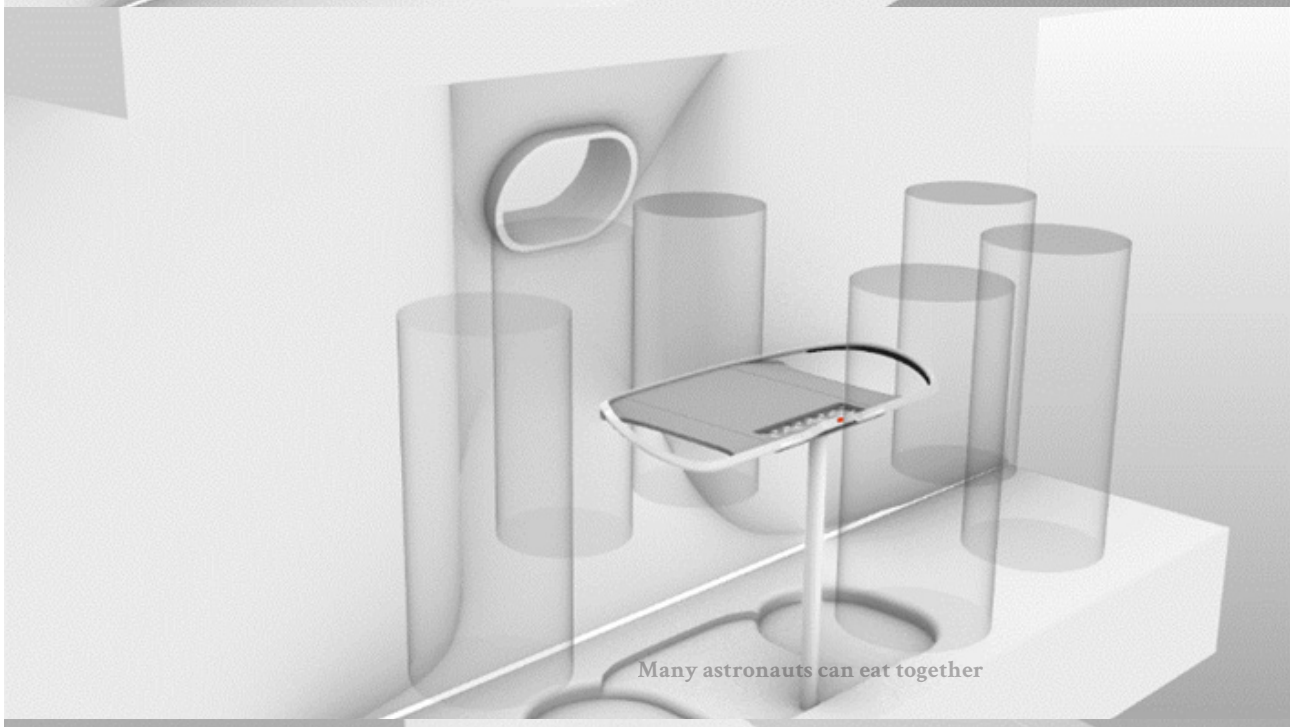


Under it a net mesh is there where we can add our spoons, scissors and knives which can be safe when we shut the rotating smaller table keeping everything closed and safe.

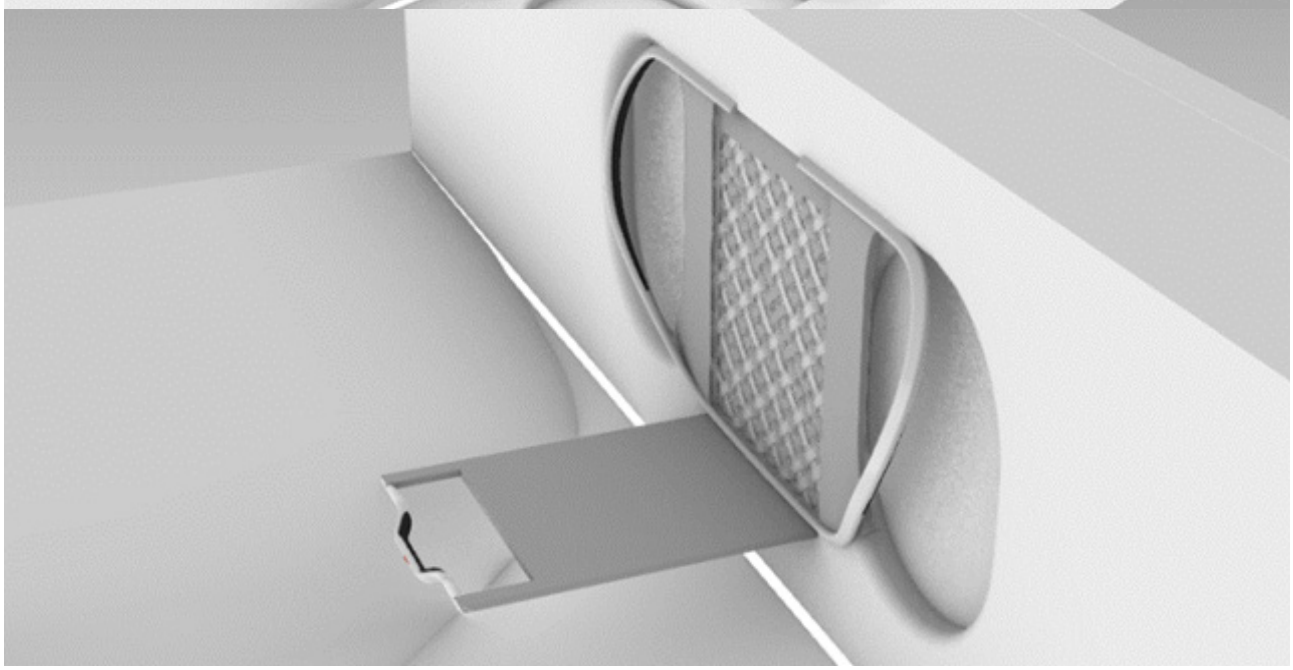


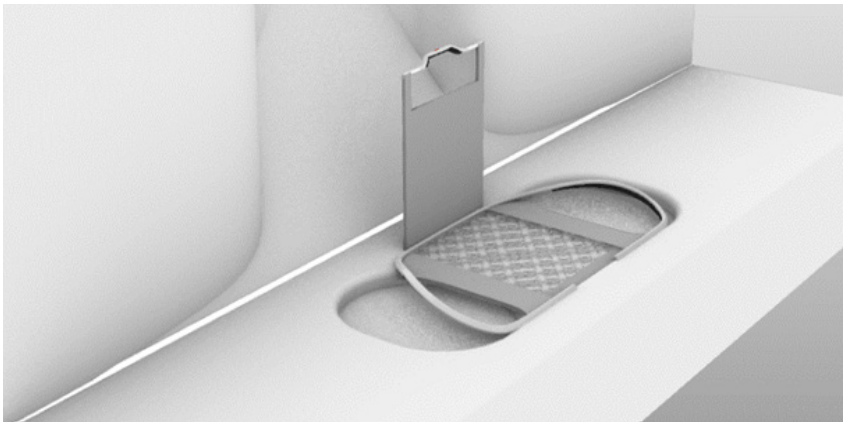
This table can also be pulled up when a lot of people want to join. This fulfills all the requirements that we gathered by conducting user research from the questioners.

Round edges – Safety
Mesh and cover – Easy to clean and organize
Pull function and rotating table – Easy to navigate around
Enough Spacing
Conducive for social interaction
Keeps the floating things organized with the help of mesh, table cover and Velcro
The hollow surface can be used as a storage space, and the cover can also help with that.
The table is easy to access as it is not shifted to the side but in the center.

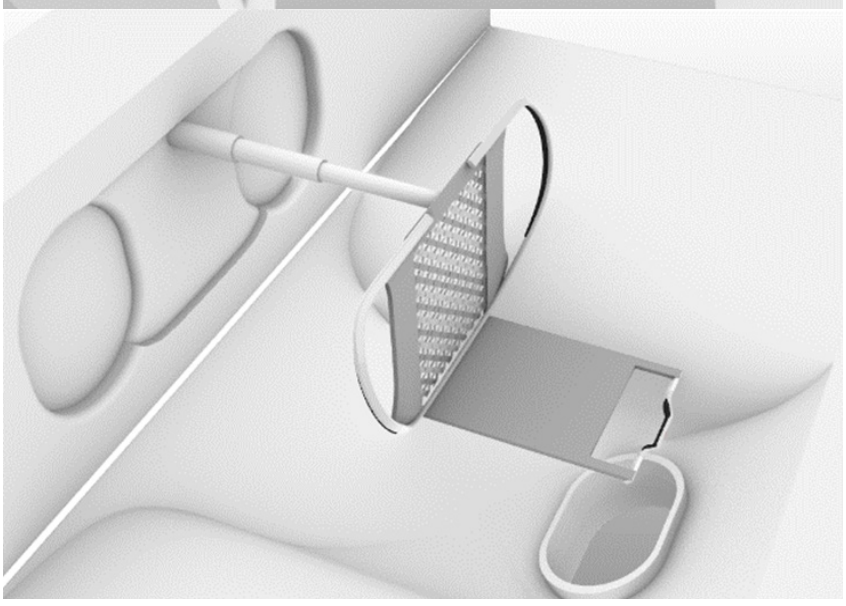


Many astronauts can eat together



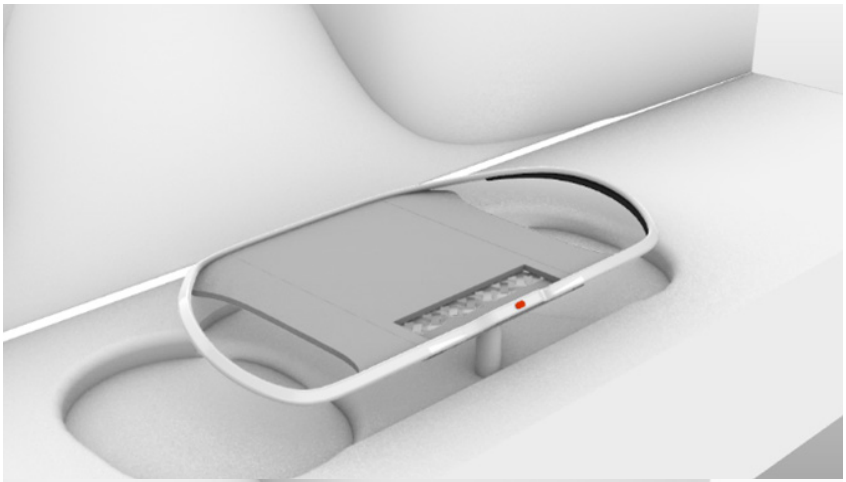


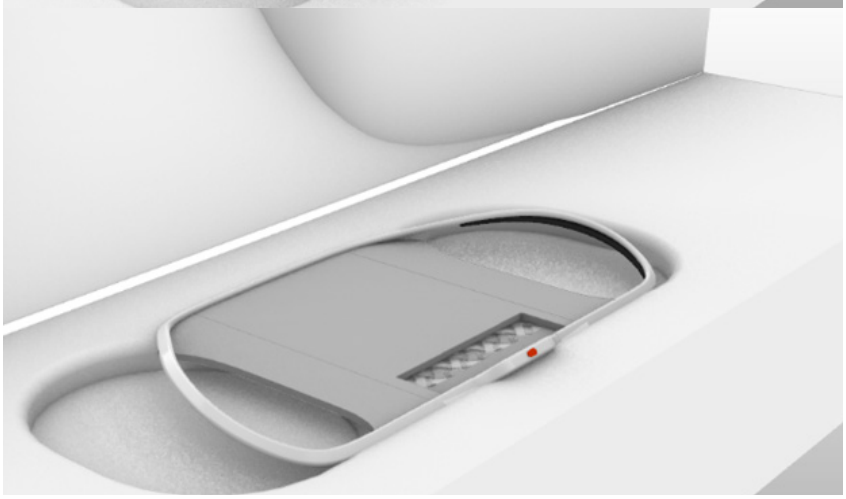
Can be used for lesser people and functions as a lid for storage part with mesh. Thus keeps things organized.



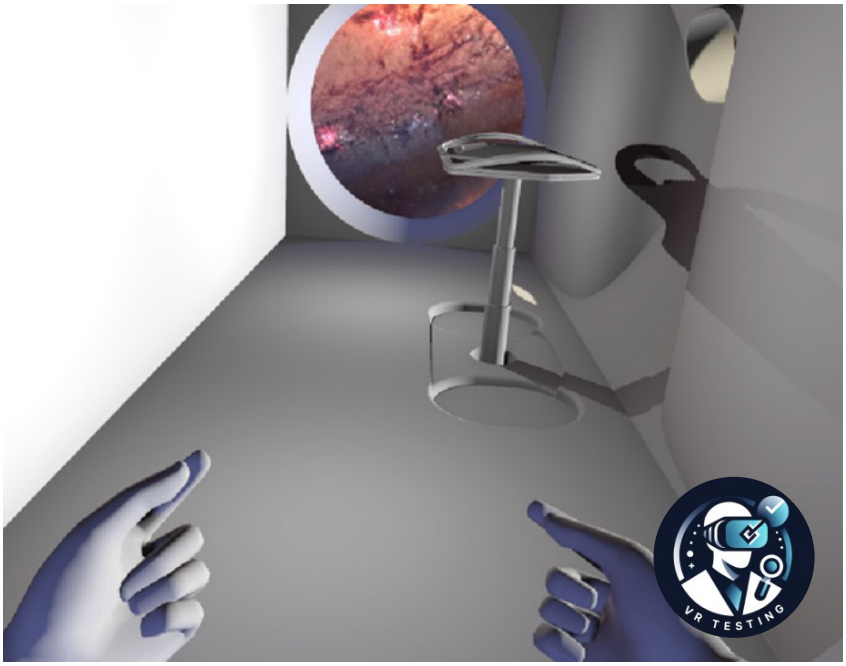
Can be used both sides

Functions as a holding handle as well. The holding handles have a soft padding without sharp edges, this could be reproduced across the space station where the hand railings are hard and edgy.





Fits easily into the wall

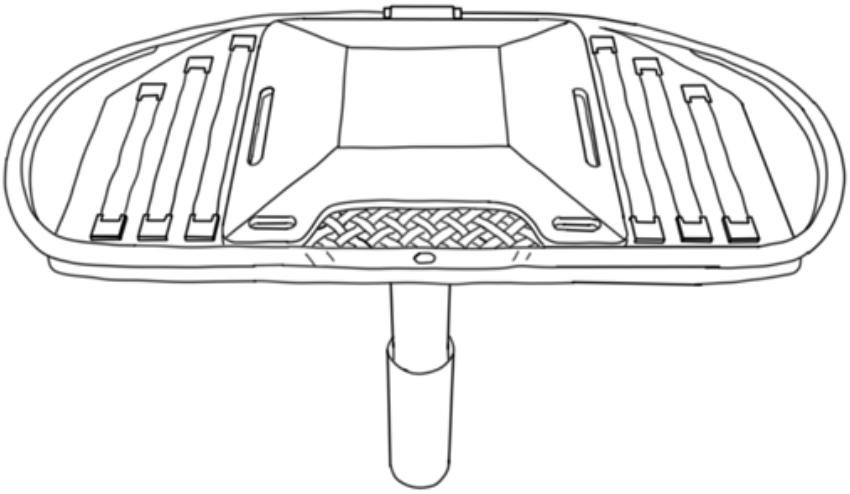


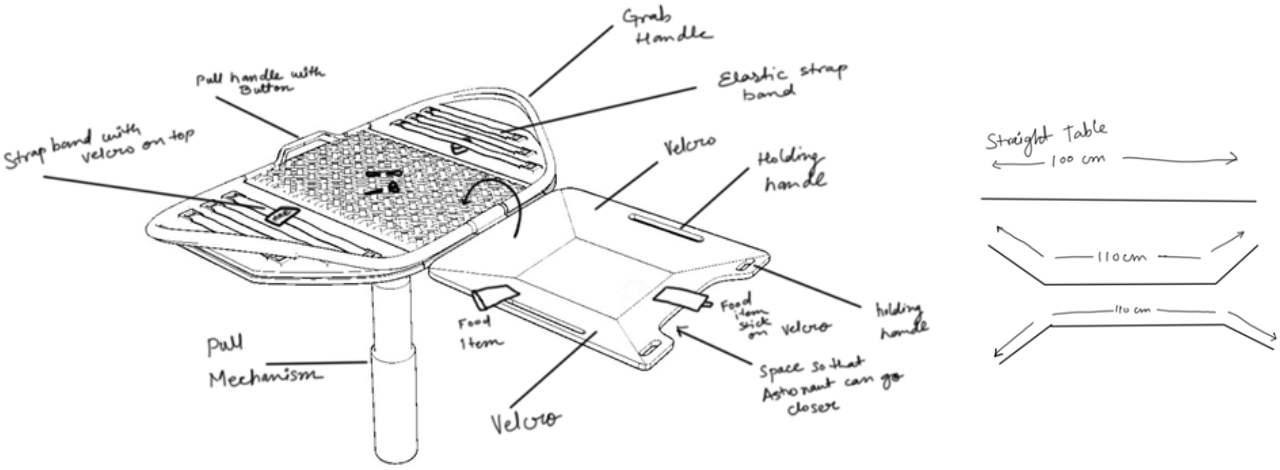
But the storage was not big and when tried in Virtual Reality Simulation I found out that, to reach the table from the side would be a problem. The handle of the cover of the table also should be attached to the main body and not to the Rotating table (Tale cover/ Table Top).
Other than that in VR test it showed that when rotated 90 degree it does not accomodate the fewer people easily as it opened to the side of the window giving no place to add the handrail for the placement of legs. So the changes would be -

1. The whole table should be readjusted to the center.
2. The whole table should be rotated 180 degree
3. Handle with button for pulling out of the table should be attached to the main table
4. There should be some handrail for keeping the person at place.

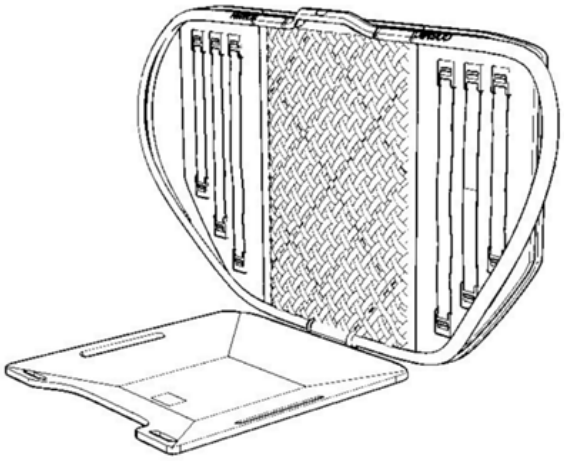
5.5 Final Concept

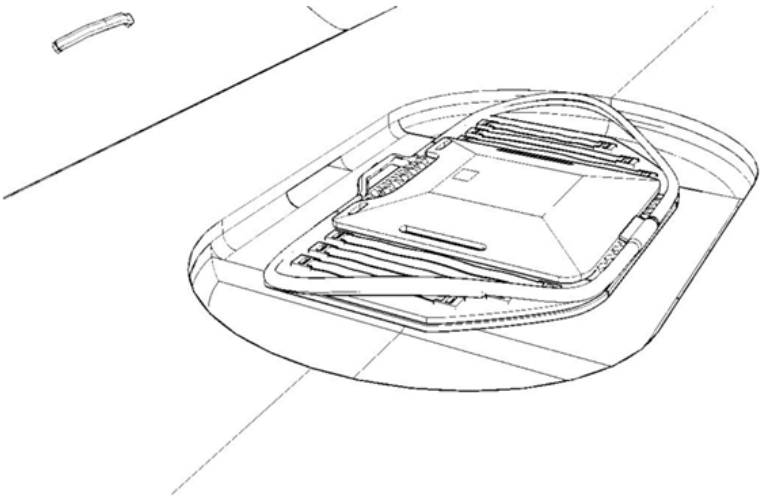
This "Final Concept" in the context of designing a zero-gravity dining table with Virtual Reality (VR) integration is the culmination of all research, brainstorming, and design development. It represents the refined, polished version of your idea, ready to be presented as a viable solution. Let's explore what goes into developing and defining this final concept in simple and understandable terms





The Rotating Table Top (Table Cover) can be changed to be angled, this leads to more surface space, so extra things can stick on it and it gives more space when the table top is closed.

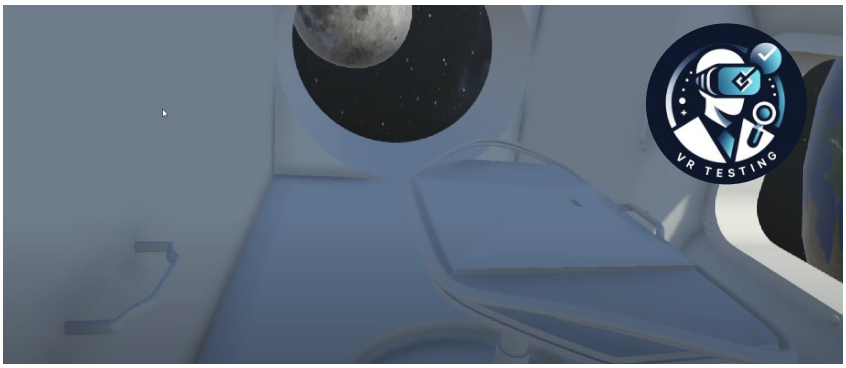


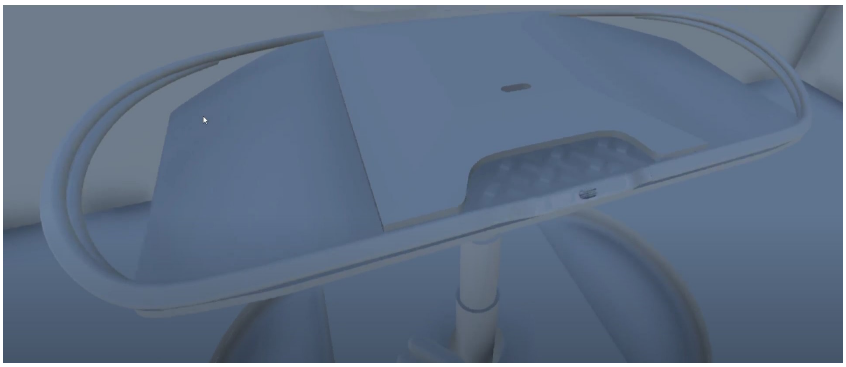


As discussed before, design cannot be done in isolation, The slot for holding is designed so that an astronaut can grab it whiling pulling out and also a handle can be added to which leg can be put in to stay stable and also to put the table inside.

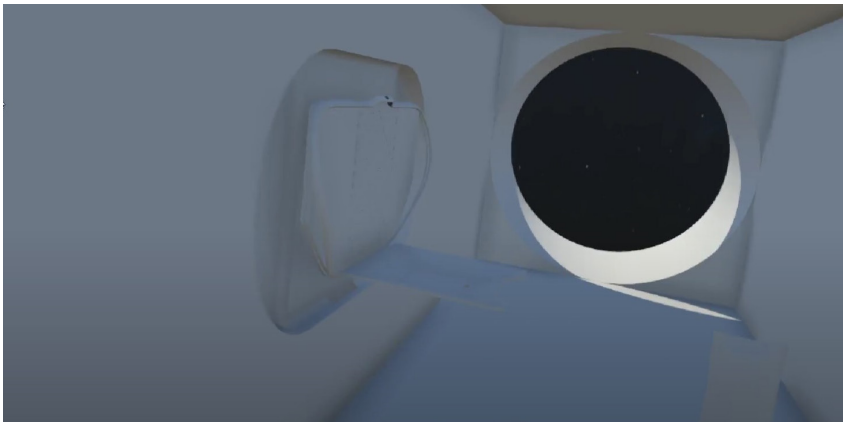
Testing the final concept in VR:

Testing the final concept's model in Virtual Reality will help us understand if we are facing those same problems that we faced in the original design again.





When pulled out



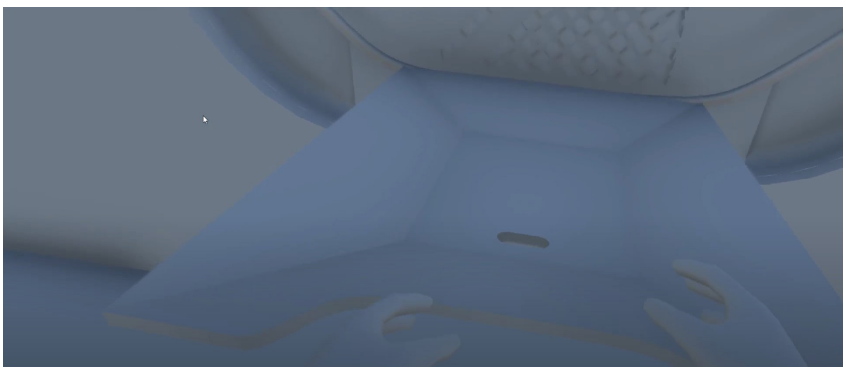
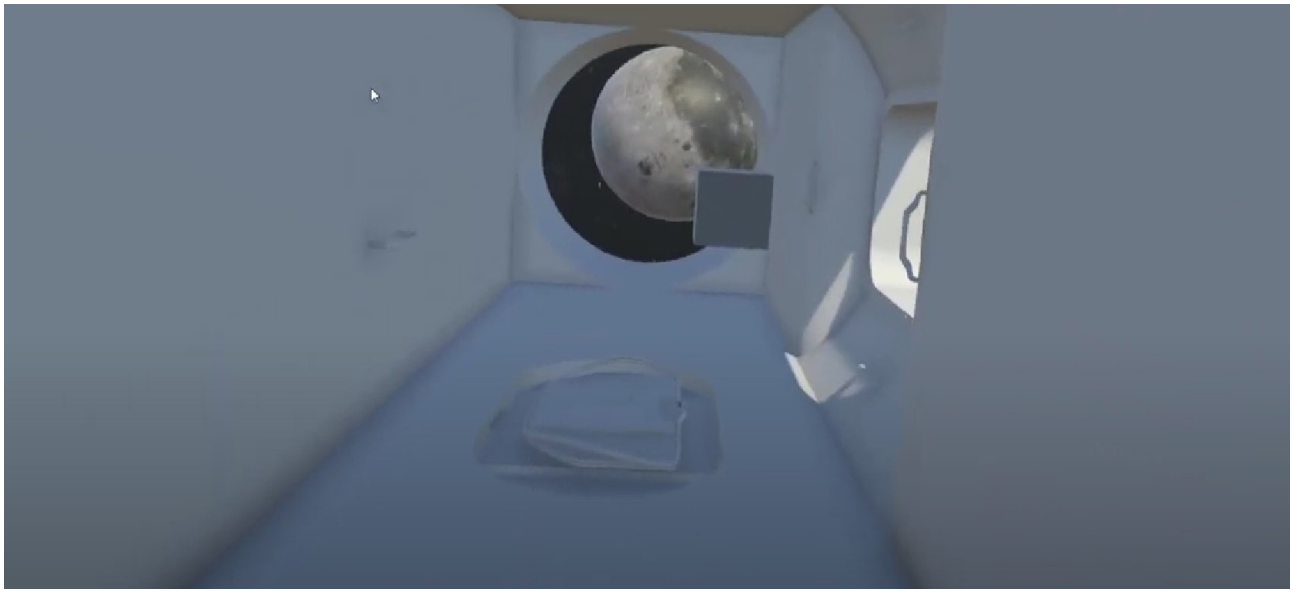
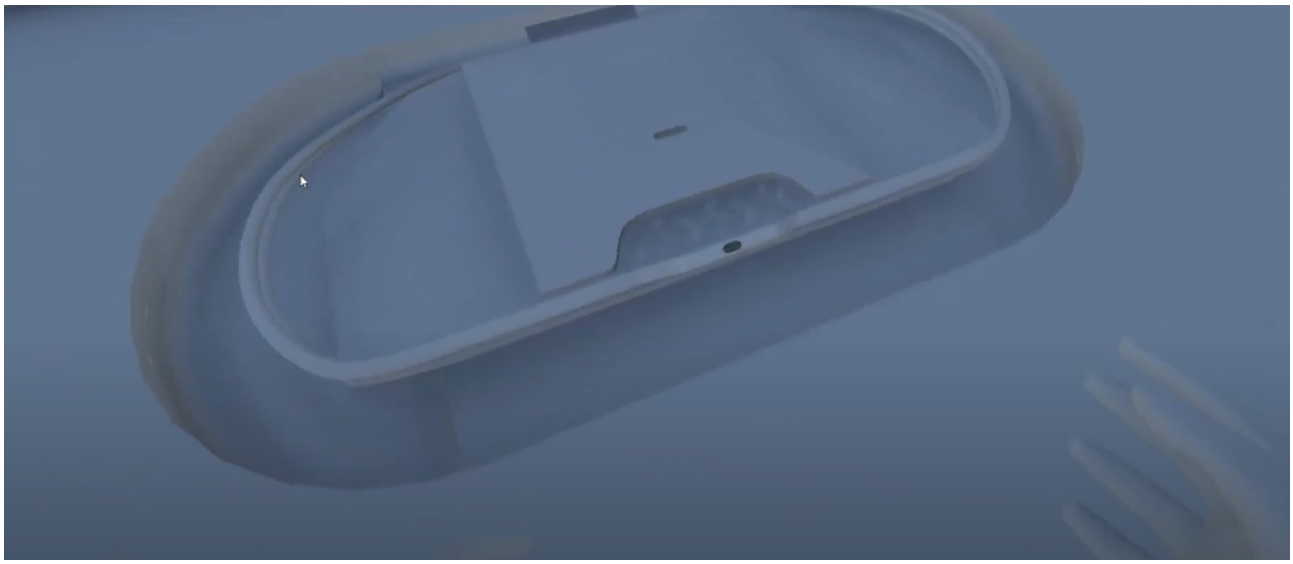


Table top opened (90 degree perspective rotating)

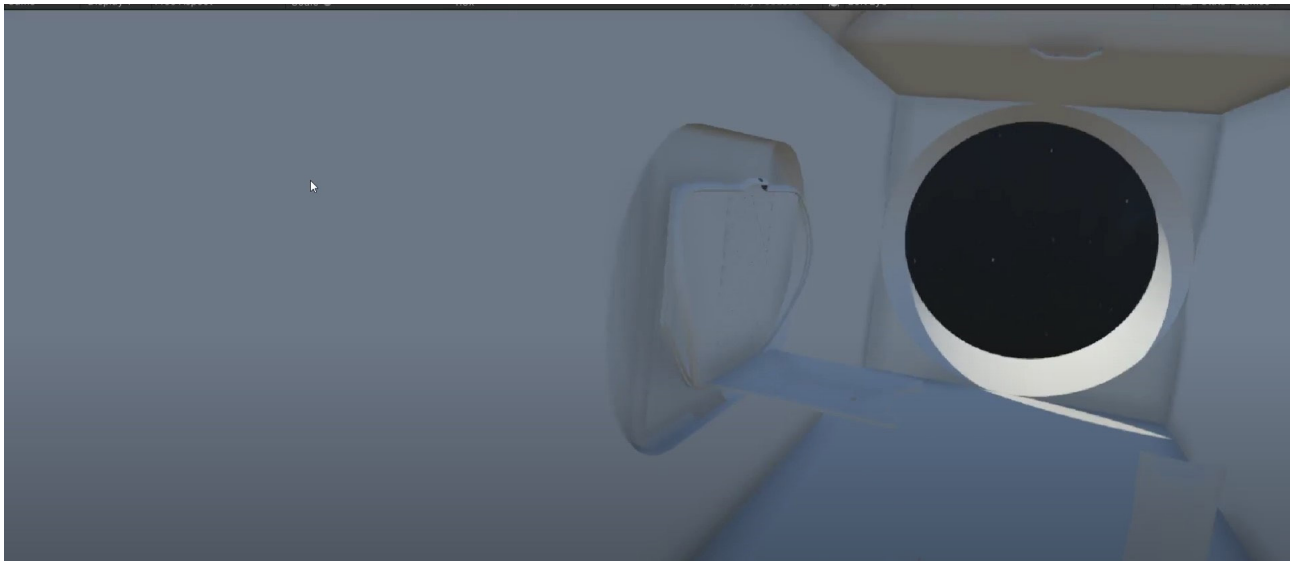


Easy to navigate around, Easy to access and the table takes no space when not in use as it goes back into the walls of space station after the use.



Ample storage space both inside the table and outside of it.

Extendable thus it accomodates lots of people which is essential for the astronauts as this makes them interact with each other more.



The net mesh can store things like spoon and scissor inside it which makes it safe and easy to clean, The PEEK carbon fiber material does not collect dirt or it does not stick to them which makes it easy to clean. The material is also fireproof ad strong which makes the table safe design wise but the round edges of the table and soft holding handles makes the design safe as well.

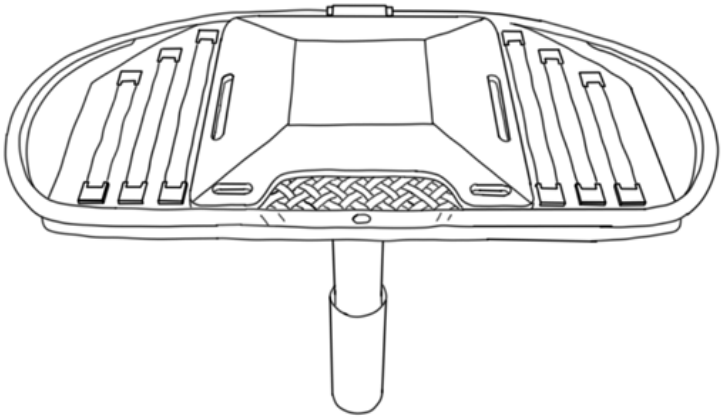
The design can be used for less people and also for larger group of people which makes it conductive for social interaction.
The handles makes it easy to navigate around bout around the table as well as around the space station.
Using it in VR showed that design is visually appealing and has a lots of potentianl due to the fact that it can have add-ons(on which you can add games) which can improve the social interactions among the space travelers.

Thus the design is ----

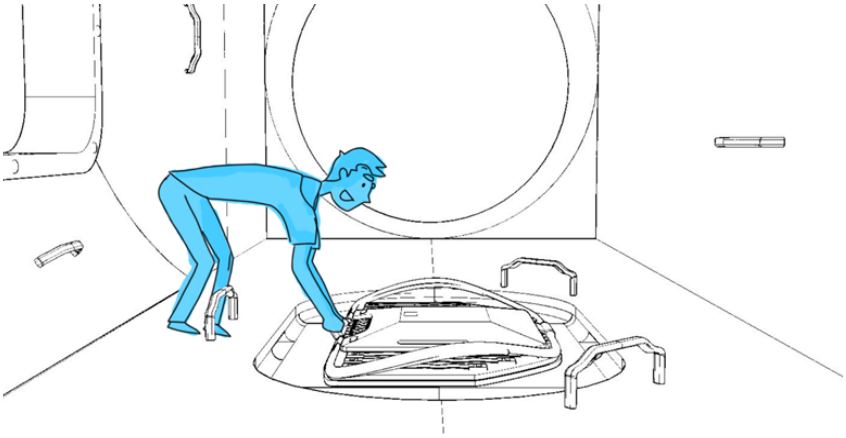
6. Project Analysis/ Experimentation

6.1 Presentation of Initial Designs and Sketches

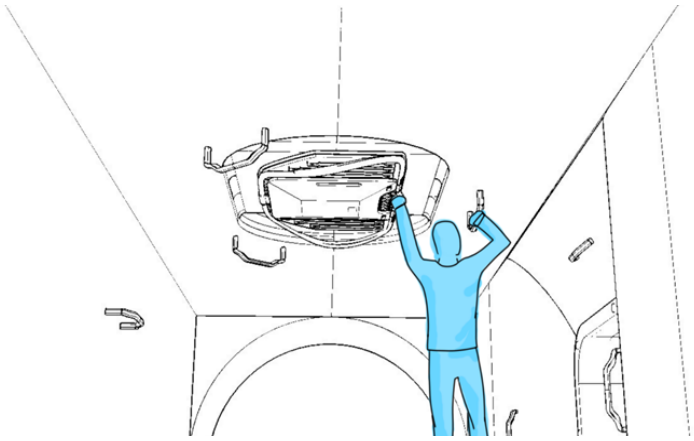
In this process of developing a zero-gravity dining table with Virtual Reality (VR) integration, the "Presentation of Initial Designs and Sketches" is a pivotal phase. This stage is where the ideas and brainstorming take a tangible (in VR way) form. It involves creating and showing the first visual representations of your concept. Let's delve into what this entails in simple and understandable terms:



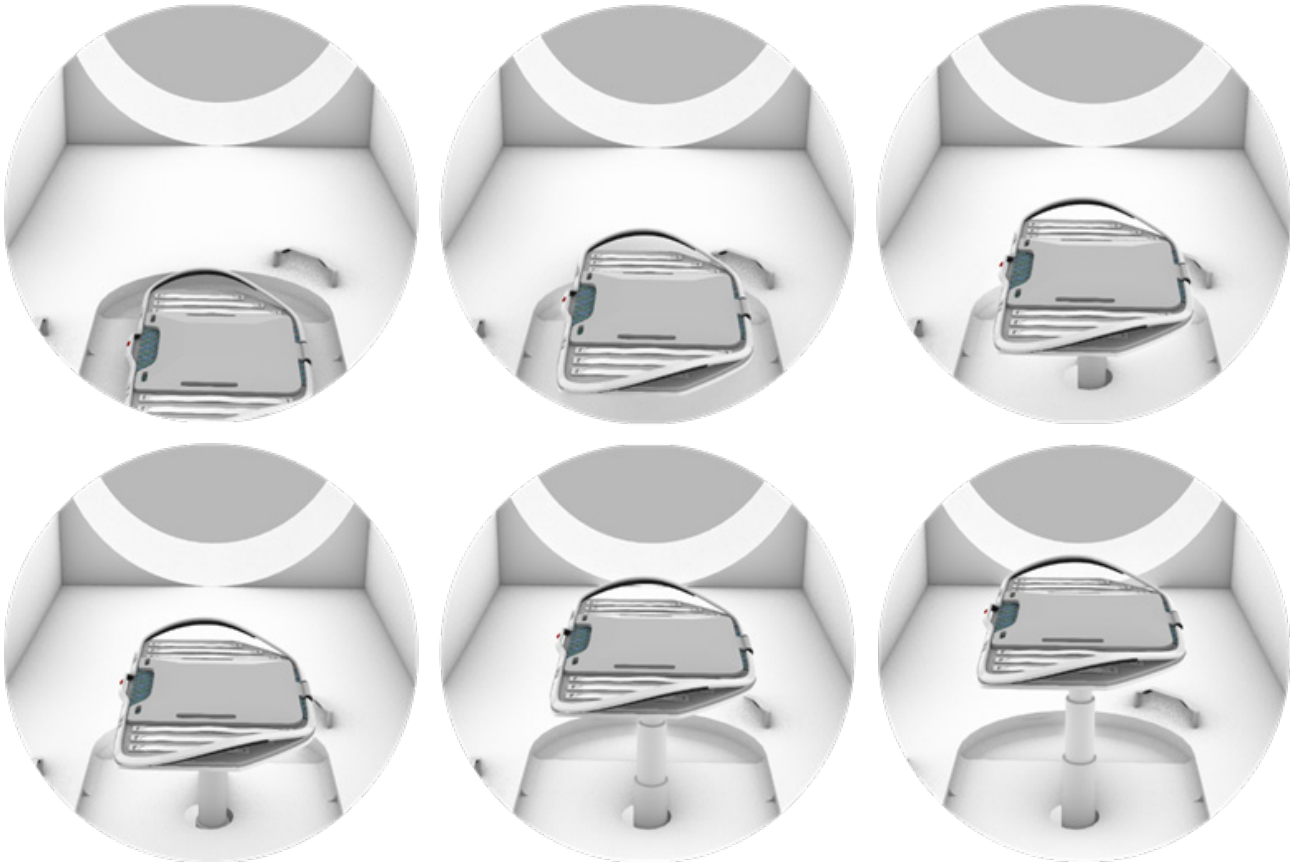
Here are the ways to approach the Table



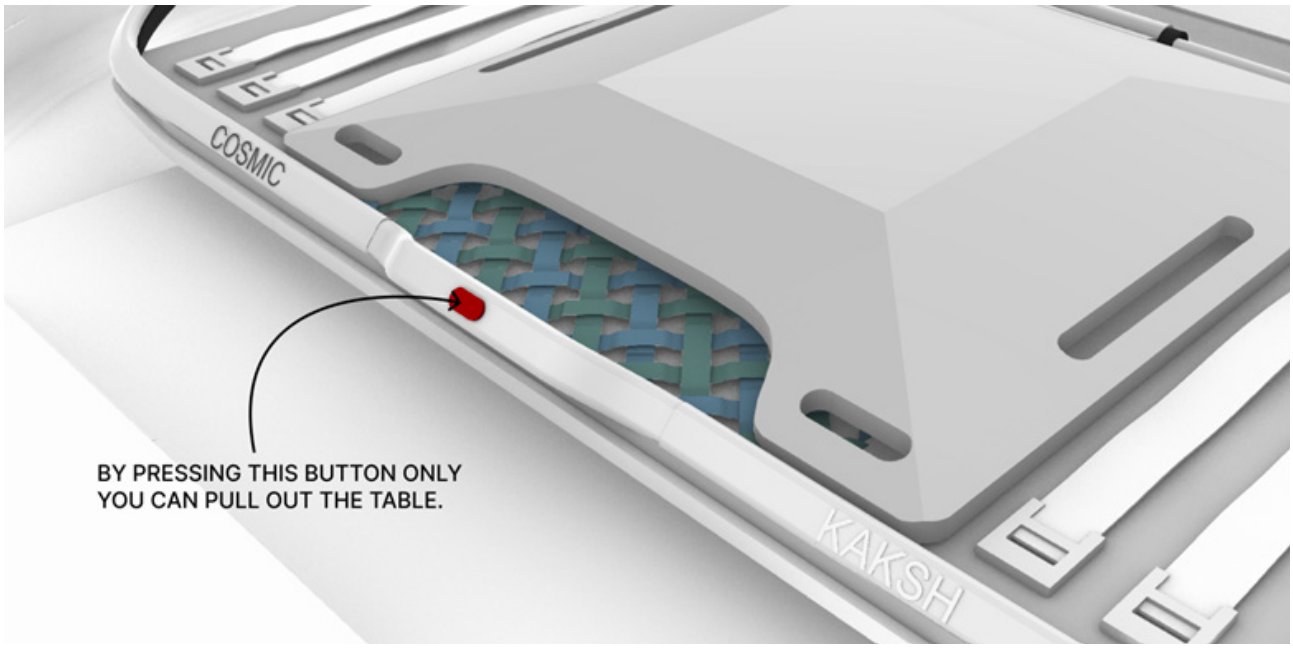
From the same plane (according to perspective you are pulling up)



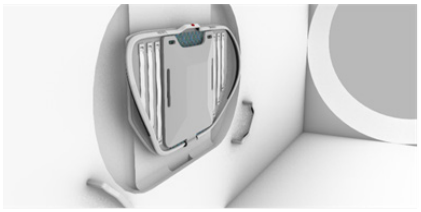
From the opposite plane (according to perspective you are pulling down), and we can even approach it and open it from the perpendicular plane like opening a door (in that perspective you have to pull sideways).

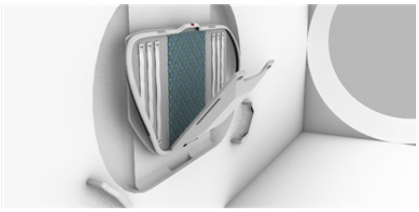


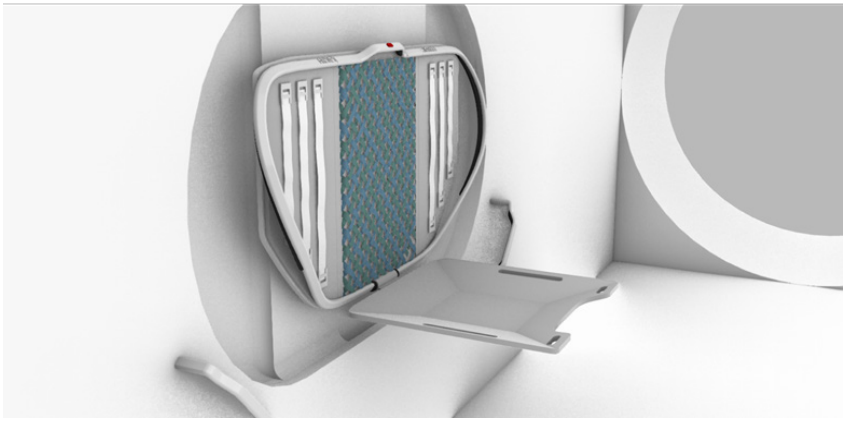
The pulling function basically works with a press of a button which takes out the table which can accommodate almost every astronaut inside the space station (ISS)



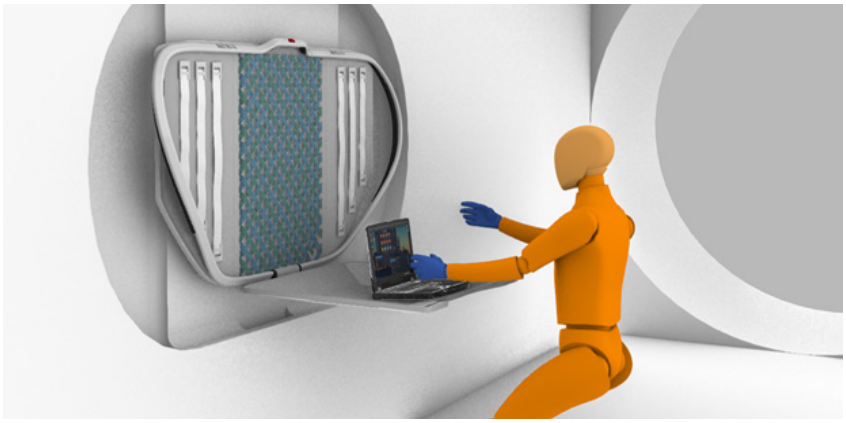
It will also have some addons on which games customized according to the zero gravity can be played.







This is the rotation of table to 90 degree which can accommodate a smaller group of people and can also work as awork table. It has Velcro on the side which helps in keeping the things in place, It also works as a lid that further helps in organizing the items which are kept in mesh.

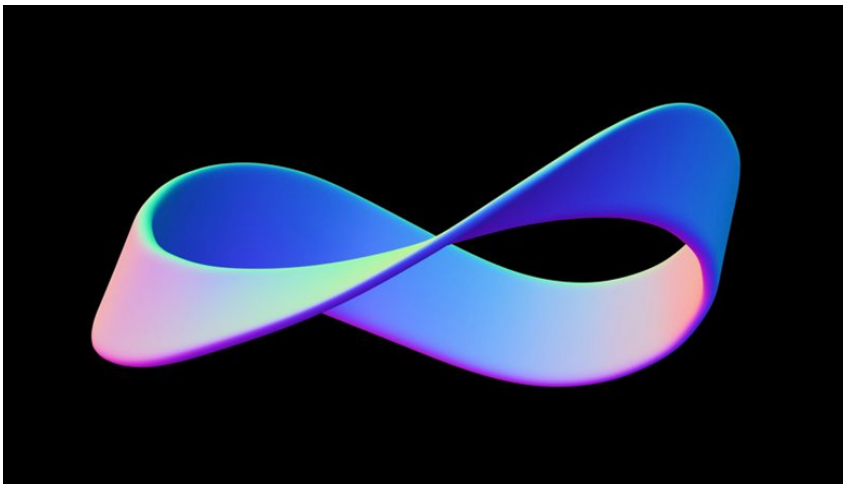


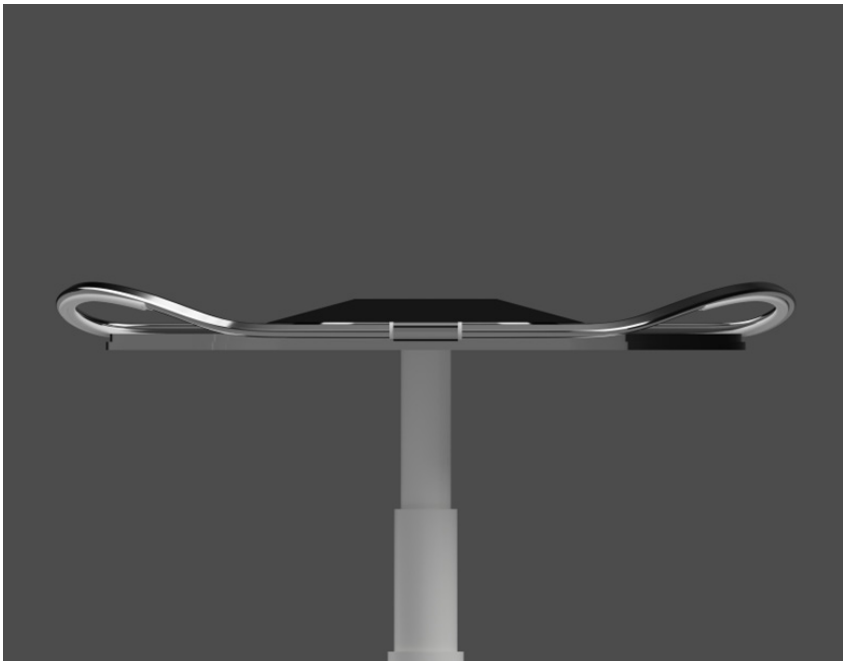
Incorporating Functionality: Even in these early sketches, think about how the table will function in zero gravity. How will items stay on the table? How will the VR system be accessed and used?

When looked from side table looks like a Möbius strip which is a two-dimensional mathematical construct, and it is not directly related to three-dimensional space or the physics of our physical universe. However, it can be used as a concept or metaphor to explore certain ideas related to space, topology, and geometry.

Artists and designers often use the Möbius strip as a source of inspiration for creating visually interesting and thought-provoking objects and artworks. While these creations may exist in three-dimensional space, they draw on the Möbius strip's properties to create optical illusions and novel spatial experiences. The Möbius strip, along with other mathematical objects, can be used to create abstract representations of space and spatial relationships. These abstractions can be useful in mathematical modeling and problem-solving in various fields, including physics and engineering.

This helps in making the table look aesthetic.





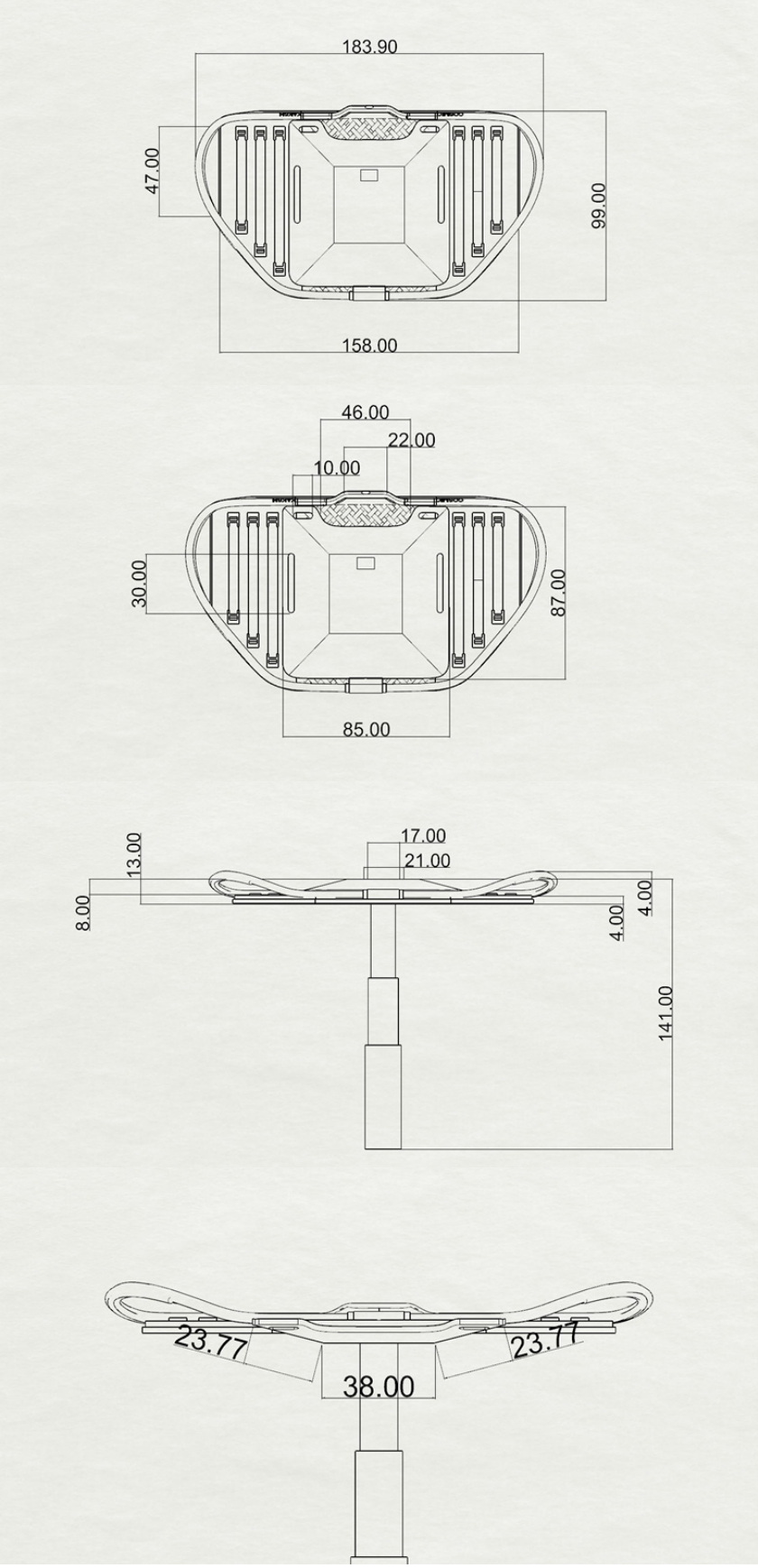
But it also looks like uterus

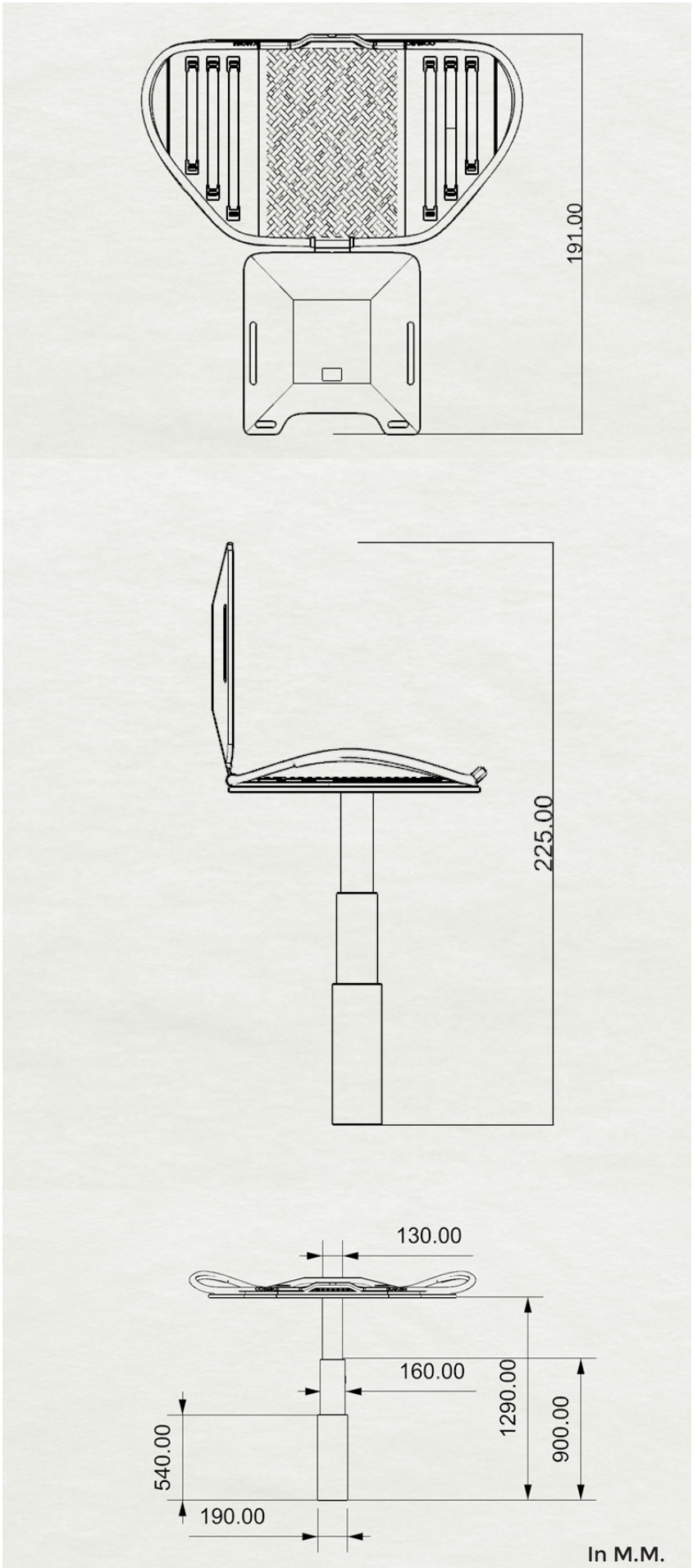
6.2 Geometric Study and Material Selection

In the context of designing a zero-gravity dining table with Virtual Reality (VR) integration, "Geometric Study and Material Selection" are key steps that play a crucial role in determining the feasibility and success of your product. Let's break these concepts down into simple, understandable terms:

Geometric Study:

Here is a rough measures of all the dmensions ofthe table

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Understanding Shapes and Sizes:

Geometric study involves analyzing the shapes and sizes that will work best for your dining table in zero gravity. This means thinking about how the table will fit into the space environment, how people will interact with it, and how it can accommodate VR equipment.

Space Efficiency:

In a zero-gravity environment like a space station, every inch of space is valuable. This design maximizes functionality without taking up unnecessary room. This was possible because the table can be folded and retracted when not in use.

User Interaction:

By considering how astronauts will use the table which includes their ease of reaching for things, they can easily sit or float near the table.

Ergonomics in Zero Gravity:

Traditional ergonomic principles are adapted for zero gravity. The design ensures comfort and ease of use in a weightless environment, which presents unique challenges for posture and movement.

Material Selection:

Choosing Suitable Materials: The materials for your dining table need to be carefully selected to suit the zero-gravity environment. They should be lightweight (to minimize launch costs), durable, and safe for use in space. That's why this dining table for the International Space Station is using PEEK carbon fiber that involves a blend of careful material selection, safety considerations, compatibility with advanced technology, aesthetic balance, and sustainability. Here's a detailed exploration of these aspects:

PEEK Carbon Fiber:

This material is an excellent choice for dining table design. PEEK (Polyether Ether Ketone) is renowned for its strength-to-weight ratio, making it ideal for the zero-gravity environment in space. Its lightweight nature significantly reduces launch costs. Additionally, carbon fiber reinforcement enhances its durability, ensuring the table can withstand the rigors of space travel and long-term use in the space station.

A 3D printed PEEK Carbon Fiber

Safety Considerations:

Non-Toxic and Fire-Resistant: PEEK is known for its high thermal stability and flame-retardant properties, making it safe for use in the confined and sensitive environment of the space station. It does not emit harmful gases, which is crucial in maintaining a safe air quality onboard.

Temperature and Radiation Resilience: This material can withstand extreme temperatures and radiation levels encountered in space, ensuring the table's longevity and safety.

Aesthetic and Functional Balance:

Visual Appeal and Texture: While the primary focus is on functionality, the aesthetic aspect of PEEK carbon fiber is also noteworthy. It possesses a sleek, modern look with a pleasing texture. This contributes positively to the ambiance, especially when combined with VR technology, enhancing the overall dining and social experience in space.

Eco-Friendliness and Recyclability: PEEK is a sustainable option. It's eco-friendly and recyclable, aligning with the growing emphasis on sustainability in space missions.

Ease of Cleaning and Maintenance: In a zero-gravity environment, ease of cleaning is paramount. PEEK carbon fiber's smooth surface is easy to wipe down and maintain, resistant to stains and spills, which are inevitable in a dining setting.

In conclusion, PEEK carbon fiber is a strategic choice for constructing a dining table for the International Space Station. Its lightweight and durable nature, coupled with safety, aesthetic appeal, and sustainability, make it an ideal material for this unique and challenging environment.

6.3 Virtual Simulations and Prototypes

When developing a zero-gravity dining table with Virtual Reality (VR) integration, "Virtual Simulations and Prototypes" play a pivotal role in bringing the concept to life before it becomes a real, physical product. This step is about testing the ideas in a virtual environment

6.3.1 Selecting VR headset:

Purchasing the Meta Quest 2 for your VR development project is a strategic decision, considering several key factors:

Popularity and Market Reach:

- Widespread Adoption: Meta Quest 2, developed by Oculus (now part of Meta Platforms, Inc.), is one of the most popular VR headsets on the market. Its widespread adoption makes it an ideal platform for reaching a broad audience. By developing for the Quest 2, you are targeting a significant segment of the VR user base.

-Brand Recognition: Oculus, as a brand, has been synonymous with VR technology. Their reputation for quality and innovation has contributed to their products being some of the most sought-after in the VR market. This brand recognition can be leveraged in your development, as users often trust and prefer well-known brands.

Development and Compatibility:

-Developer-Friendly Platform: The Quest 2 is known for its developer-friendly environment. Meta provides extensive support and resources for developers, making it easier to create, test, and deploy VR applications. This support can be invaluable, especially for new developers entering the VR space.

-Cross-Platform Compatibility: One of the advantages of developing for Oculus devices is the potential for cross-platform compatibility. Applications developed for the Quest 2 can often be easily adapted for other Oculus devices or even other VR platforms, increasing the reach of your application.

Technical Capabilities:

-Advanced Features: The Quest 2 offers a range of advanced features like high-resolution display, robust tracking capabilities, and a powerful processor. These features enable a more immersive and responsive VR experience, essential for engaging VR applications.

-Wireless Freedom: The standalone, wireless nature of the Quest 2 provides users with greater freedom of movement, a crucial aspect for an immersive VR experience. This aspect can be particularly appealing for applications requiring physical activity or exploration.

User Experience:

-Ease of Use: The Quest 2 is known for its user-friendly interface and ease of setup, making it accessible to a wide range of users, from VR enthusiasts to novices. This accessibility can be a significant advantage in ensuring a wider adoption of your application.

-Community and Ecosystem: The Oculus ecosystem includes a vibrant community of users and developers, offering opportunities for feedback, collaboration, and marketing. Engaging with this community can provide valuable insights and help in refining your VR application.

Economic Considerations:

- Cost-Effective: The Quest 2 is priced competitively, making it more accessible to a broader audience compared to some high-end VR headsets. This affordability can translate to a larger user base for your application.

-Revenue Potential: Given the large user base and the supportive ecosystem, developing for the Quest 2 can present significant revenue opportunities, especially if your application meets the needs and expectations of the VR community.

In summary, choosing the Meta Quest 2 as a development platform aligns with several strategic considerations, including market reach, user experience, technical capabilities, and economic potential. This choice positions your VR project to capitalize on the growing popularity and technological advancements in the VR industry.

6.3.2 Choosing the development platform and creating a zero-gravity environment:

Choosing Unity 3D as your development platform for creating a zero-gravity VR environment, and leveraging VRTK (VR Toolkit) for this purpose, is a well-considered decision. Here's a deeper look into why this approach is effective:

Unity 3D for VR Development:

-Popularity and Support: Unity 3D is one of the most popular game development engines, widely used for VR development. Its popularity means there's a vast amount of documentation, tutorials, and community support available, making it easier to learn and troubleshoot.

-Cross-Platform Capabilities: Unity's ability to deploy across multiple platforms is a huge advantage, especially in VR, where users may have different types of hardware. This versatility allows your VR application to reach a wider audience.

-Robust Toolset: Unity provides a comprehensive suite of tools and features specifically tailored for VR development. These tools facilitate the creation of immersive and interactive VR experiences, essential for simulating a zero-gravity environment.

Leveraging VRTK:

-Foundation for VR Interactions: VRTK is a popular open-source VR toolkit for Unity. It offers a range of pre-built scripts and functionalities for common VR interactions, such as grabbing, throwing, or using UI elements in VR. By starting with VRTK, you can significantly speed up the development process.

-Customization for Zero Gravity: Customizing VRTK to create a zero-gravity environment showcases innovative use of existing tools. Zero gravity is a complex phenomenon to simulate, and adapting VRTK for this purpose demonstrates both technical skill and creative problem-solving.

Implementing Physics with RigidBody:

-Realistic Interactions: Using Unity's RigidBody component on objects allows them to interact realistically with the VR environment. In a zero-gravity setting, this means objects will float and move in a manner that mimics the absence of gravity, enhancing the immersion of your VR experience.

-Grab Interaction Mechanism: Implementing grab interactions is crucial in VR, especially in a zero-gravity setting where users expect to interact with floating objects. By enabling objects to be grabbable, you create a more engaging and interactive environment. This feature is vital for simulating the experience of being in space or a similar zero-gravity environment.

Overall Benefits:

-Community and Resources: The large communities surrounding both Unity and VRTK provide valuable resources for troubleshooting, feedback, and sharing ideas. This can be incredibly beneficial for overcoming development challenges and improving your project.

-Scalability and Flexibility: Unity's flexibility allows for scalability in your project. You can start with basic functionalities and progressively add more complex features, such as advanced physics interactions or VR-specific effects.

-Cost-Effective Development: Utilizing Unity and VRTK, both of which have free versions available, makes this a cost-effective solution for VR development, especially for independent developers or small teams.

In conclusion, the choice to use Unity 3D and VRTK for developing a zero-gravity VR environment aligns well with the goals of creating a realistic, immersive, and interactive VR experience. This combination of a powerful engine, a versatile toolkit, and a focus on physics and interactions sets a solid foundation for your VR project.

6.3.3 Importing Models and Implementing Mechanisms:

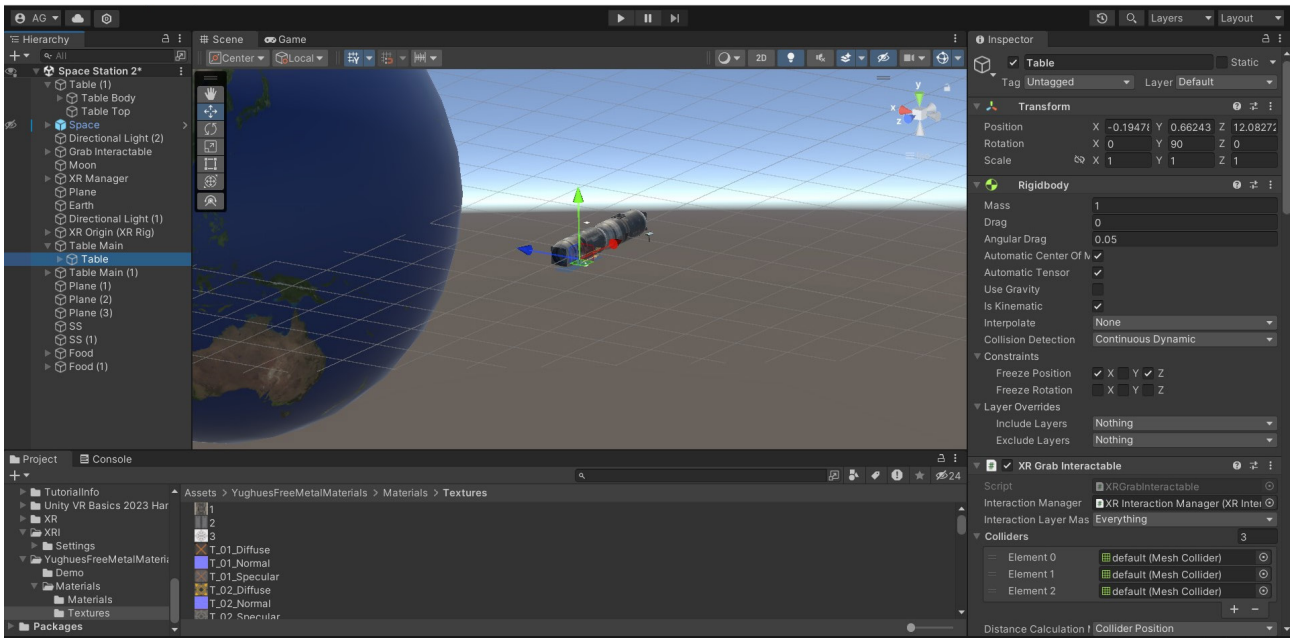
I began my project by importing a model of the space station into my Unity 3D environment. To enhance the interactivity and realism, I added 'Climb Interactable' components to the model, allowing users to navigate around the space station model in a more immersive way. Additionally, I enabled free movement along the x, y, and z axes to simulate the zero-gravity environment of space.

Next, I focused on the main table component of my project. After importing the table model into Unity, my first step was to add an 'XR Grab Interactable' component. This feature is crucial for ensuring that users can interact with the table in a virtual reality setting, mimicking real-world interactions.

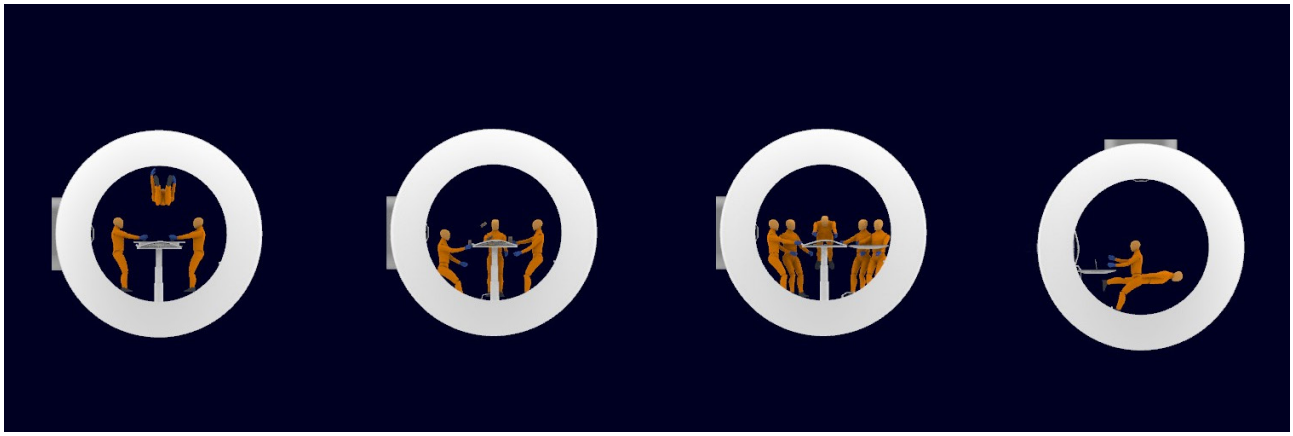
To further refine the table's functionality, I incorporated configurable joints into the model. I specifically set a linear limit on the x-axis to 1.2, ensuring that when the table is pulled out, it extends only to a certain extent. This limit is essential for maintaining realism and preventing any unrealistic stretching or movement of the table in the VR environment.

For the table top, I added it as a child object under the table body parent. I equipped it with its own 'XR Grab Interactable' and a hinge joint. The hinge joint is configured to allow rotation between 90 and 180 degrees. This functionality lets users interact with the table top, moving it as they would in a real-world scenario, further enhancing the realism of the VR experience. The angle limitation ensures that the table top's movement is controlled and mimics the physical constraints one would expect in a real table.

Overall, my approach in setting up these components was to create a realistic and interactive VR environment, where every element behaves as it would in the physical world, specifically tailored for a space station setting. My focus was on ensuring that the interactions are intuitive and contribute to an immersive experience.



7. The Project / The Product



7.1 Final Design Proposal

The "Final Design Proposal" for a zero-gravity dining table with Virtual Reality (VR) integration is a comprehensive presentation of your completed design, ready to be reviewed, manufactured, or implemented. This proposal encapsulates all the research, development, and testing phases, presenting a detailed and concrete plan for the dining table. Addressing Zero-Gravity Challenges

Dealing with Weightlessness:

In zero gravity, everything floats. This poses a significant challenge for designing a dining table where you need to ensure that food, utensils, and other items don't just float away. Solutions might include magnetic surfaces, straps, or secure compartments to keep everything in place.

Space Utilization:

Space is extremely limited in environments like spacecraft. Your dining table must be designed to make the most efficient use of the available space. This could involve foldable or multifunctional designs that can be adapted for different uses.

Safety in Zero Gravity:

Safety is a critical concern. The dining table and its components should not have sharp edges or loose parts that could cause injury or damage in a weightless environment. Materials should be fire-resistant and emit no harmful gases.

Comfort and Accessibility:

The table should be ergonomically designed to accommodate the unique ways astronauts move and work in zero gravity. This means considering how they will approach and use the table and how they can comfortably eat while floating.

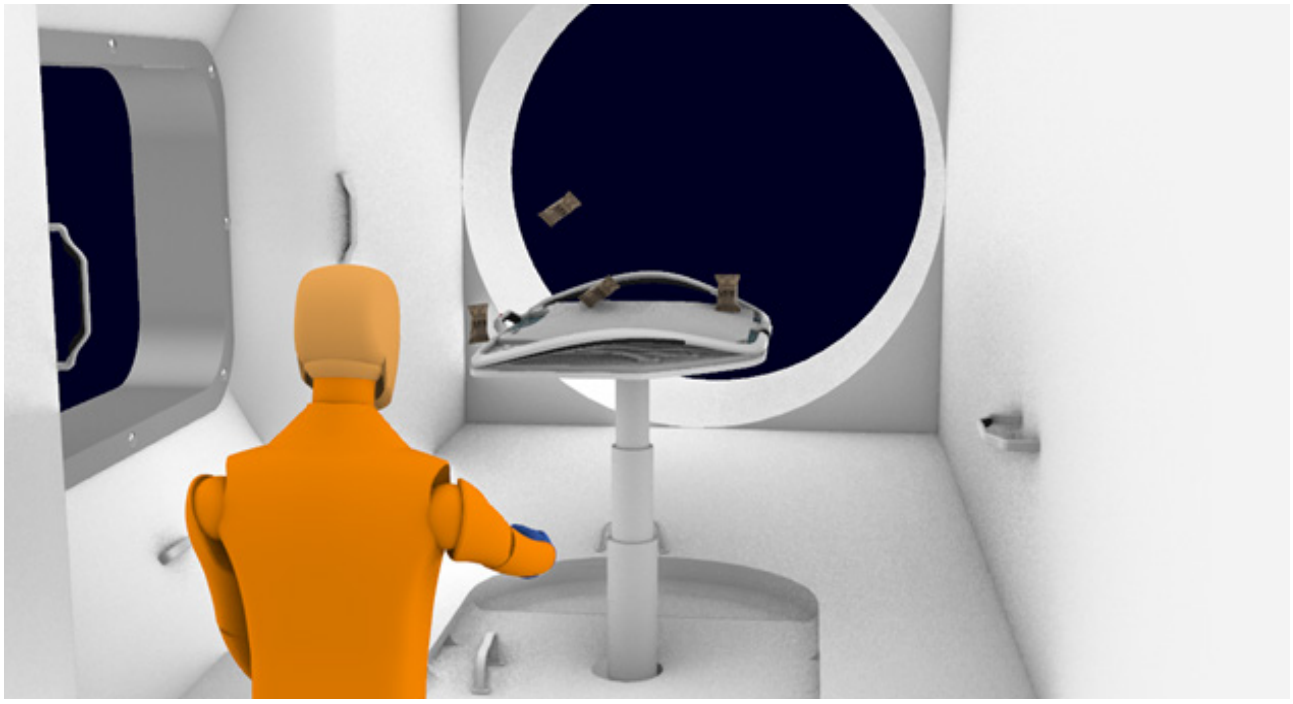
Overview of the Final Design:

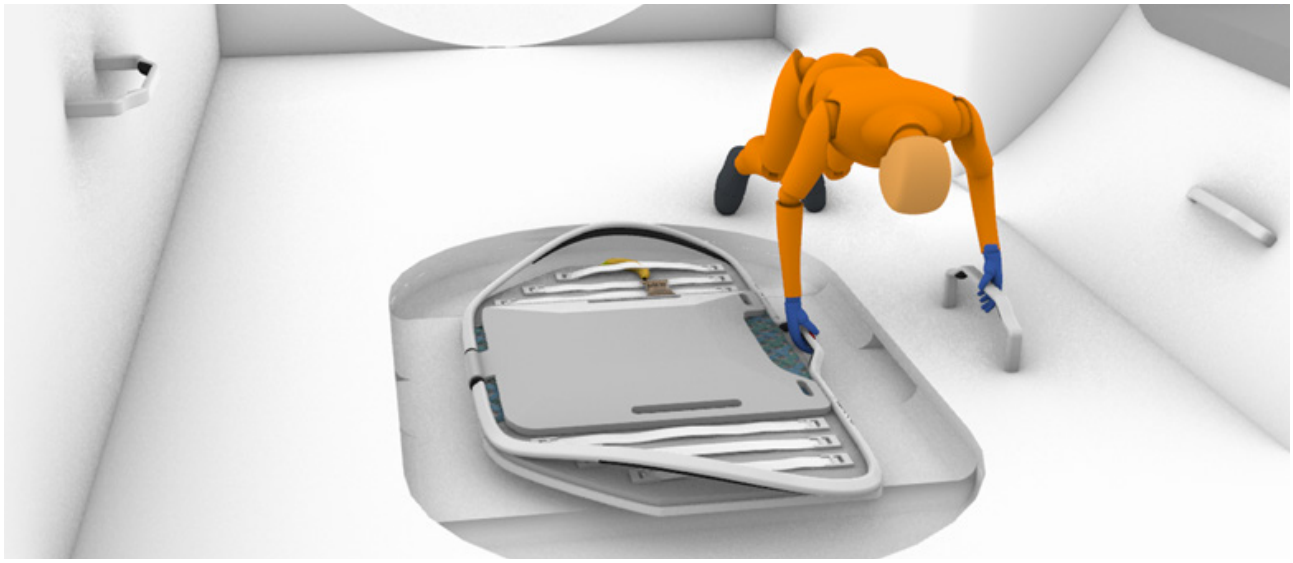
After making the adjustment and brainstorming I reached the final part that includes the Final Design, Let's take a look at its functions, how it stands out from other designs and how it can change the living of astronauts, how the table is suited for use in zero gravity. For instance, how it secures food and utensils, how astronauts can comfortably eat at the table, and how it manages issues like floating food or liquids. We will divide it in 4 Part –

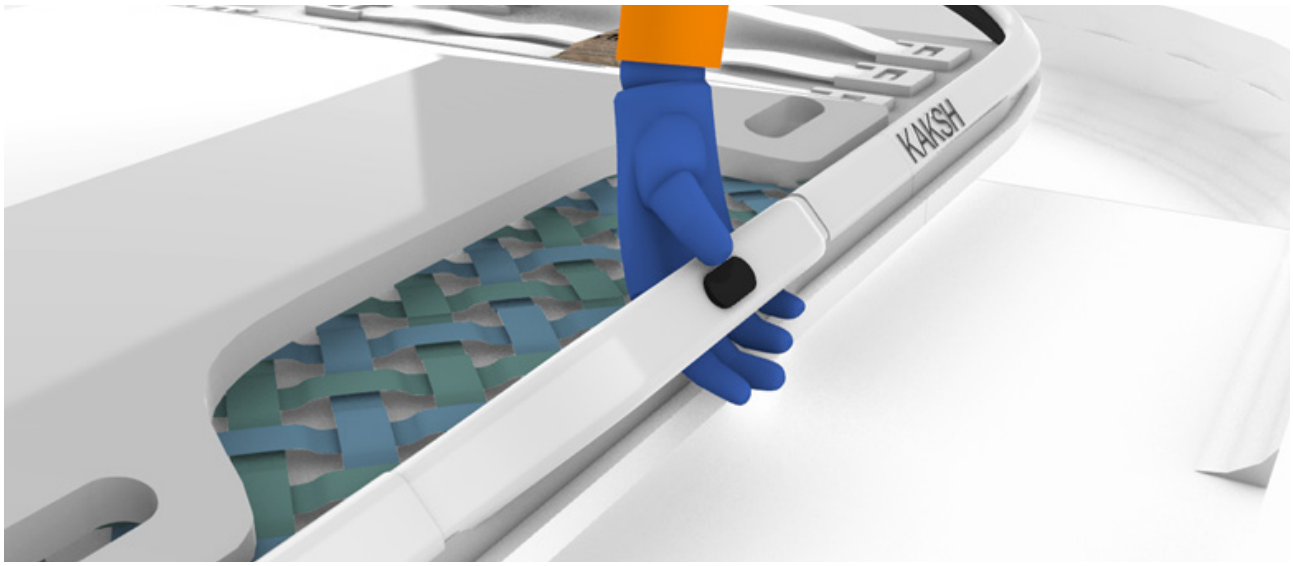
1. Pulled out
2. Pulled out with table top opened 180 Degree
3. Pushed in with table top opened 90 degree (perspective will turn 90 degrees clockwise)
4. Add-ons and additional designs

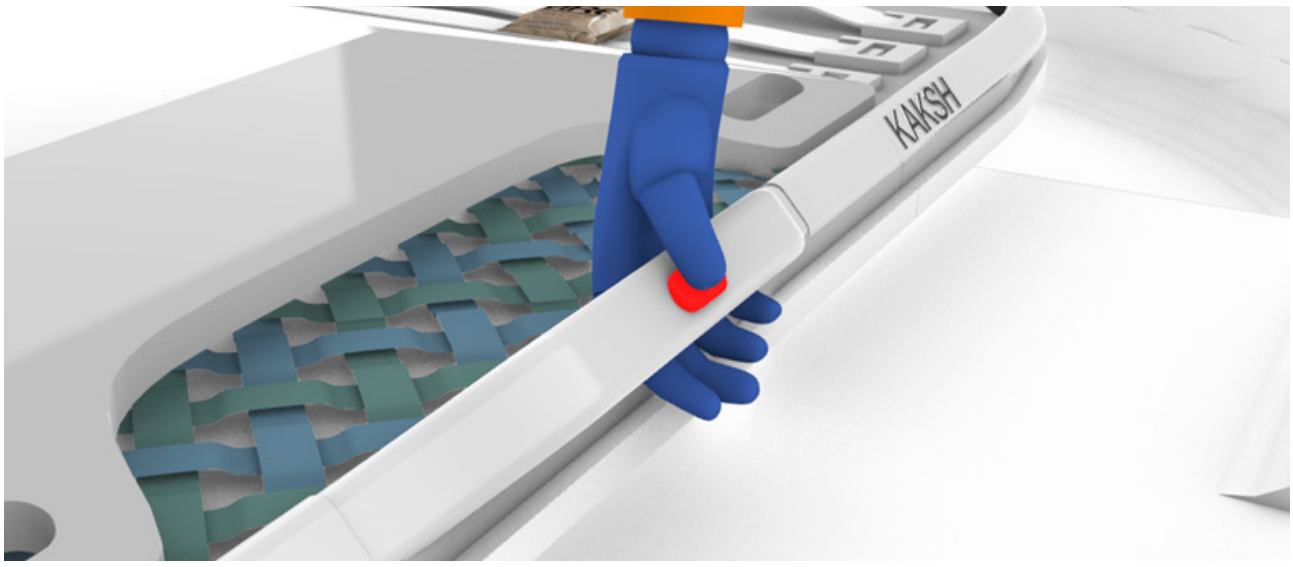
This proposal includes sketches, diagrams, or 3D renderings of the dining table. These visuals help in understanding the design and functionality of the table in a visual way.

1. Pulled out:

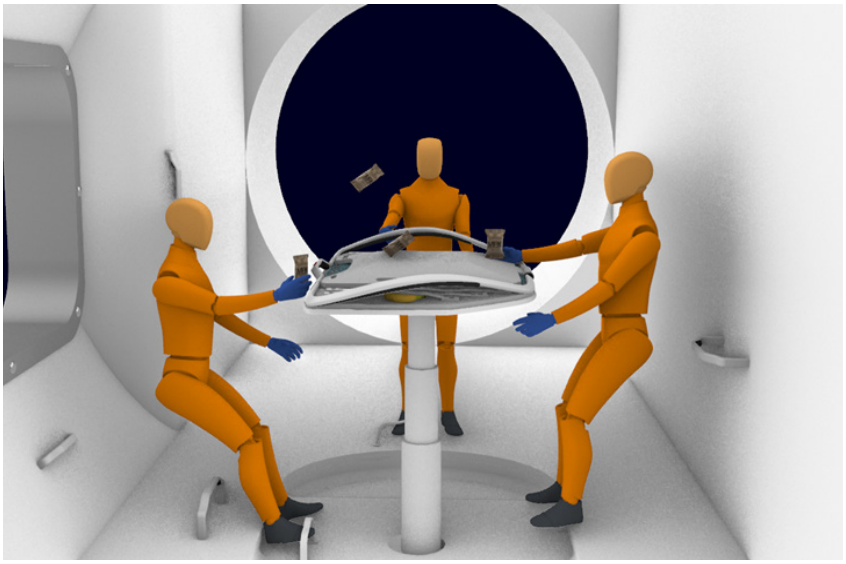








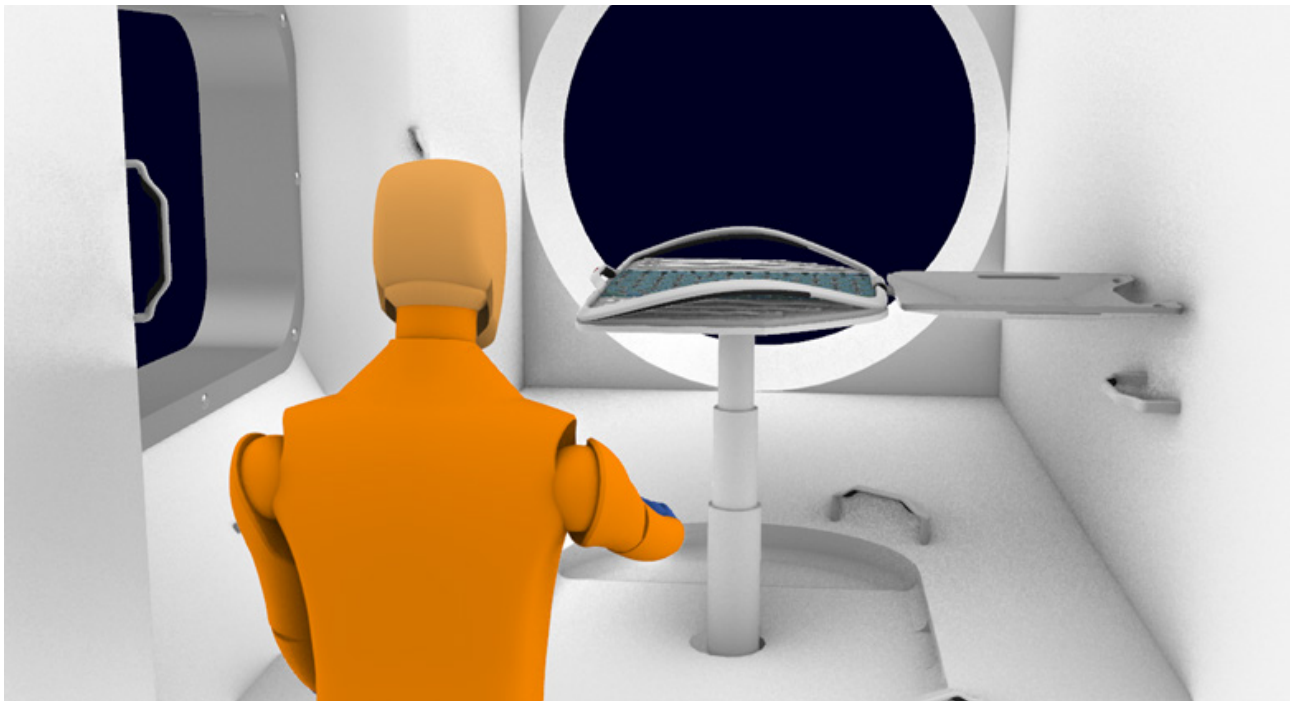
The way to pull the table out is by pressing the button on the handle and pulling it Up/Down or Side. But to do that you have to grab the hand rail or fix your legs into them, or else instead of you pulling table closer to you the table will pull you closer to itself.

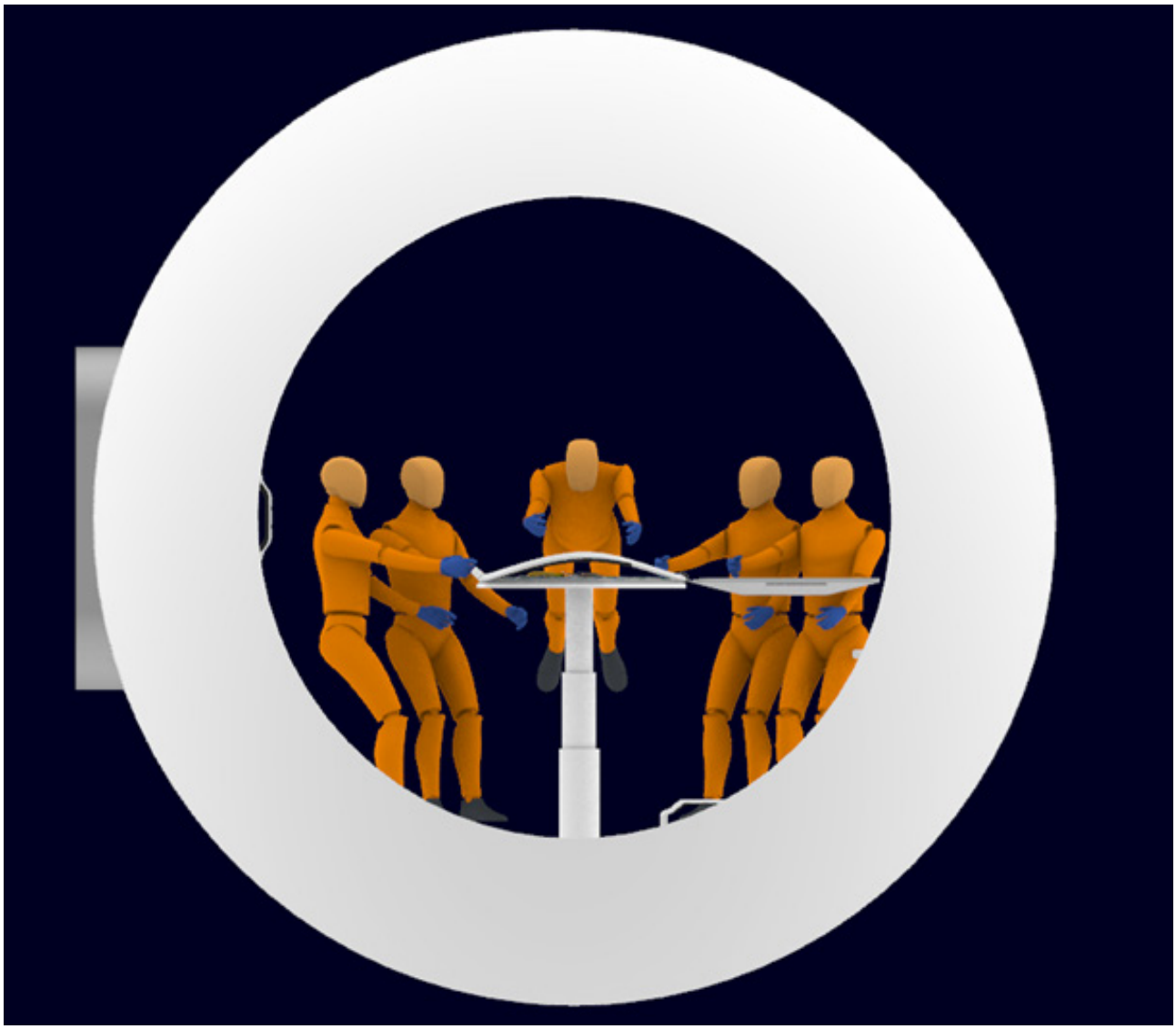


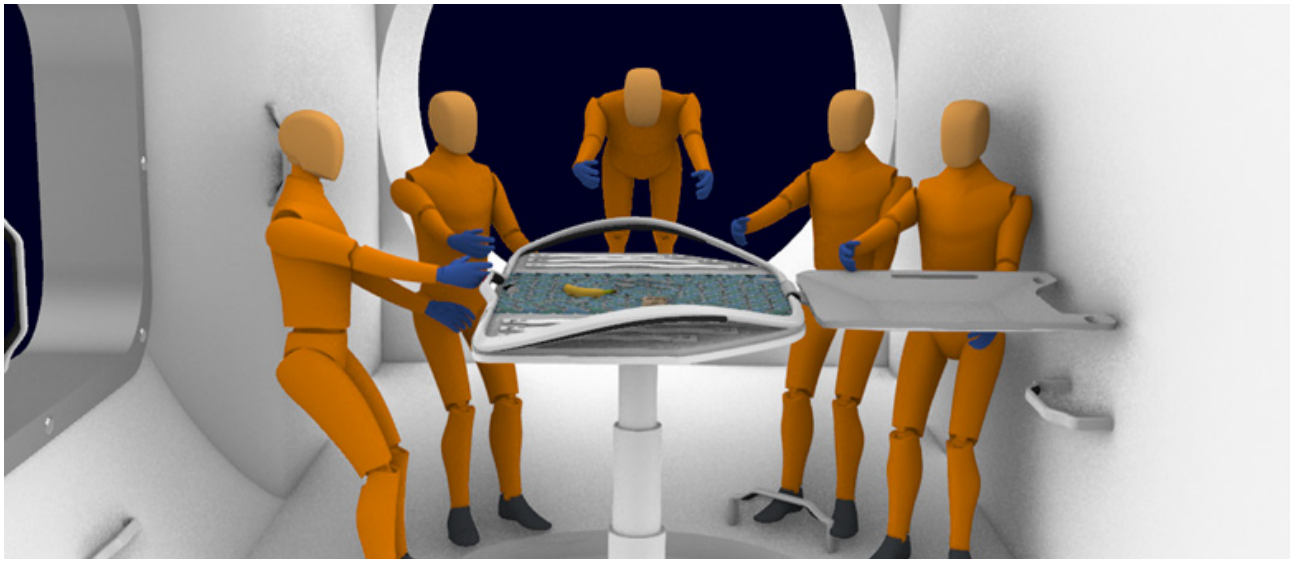
As the table can be used in many ways here is how it works when pulled out.

The table has handrails that helps in holding and keeping the user in place and not float away, the handrail also works as a normal handrail when the table is closed and pushed back inside. This helps the astronauts in navigating around the space station.

2. Pulled out with table top open 180
Degree:





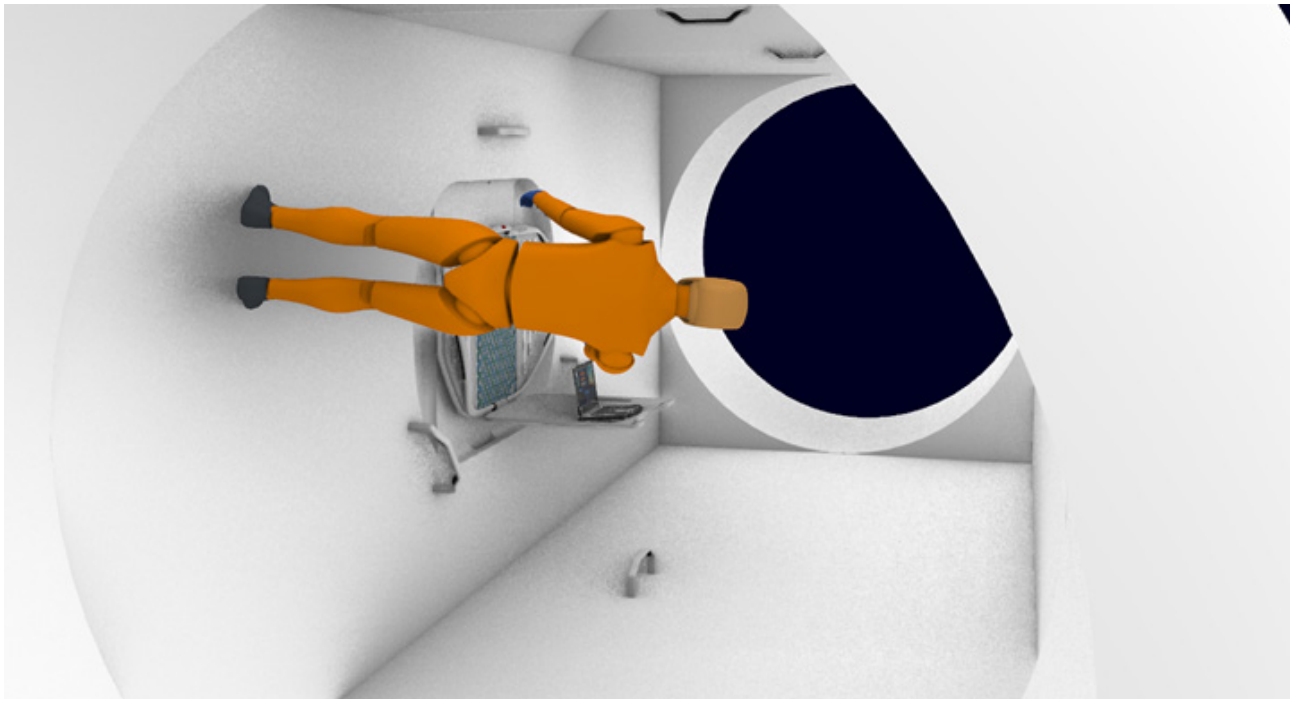


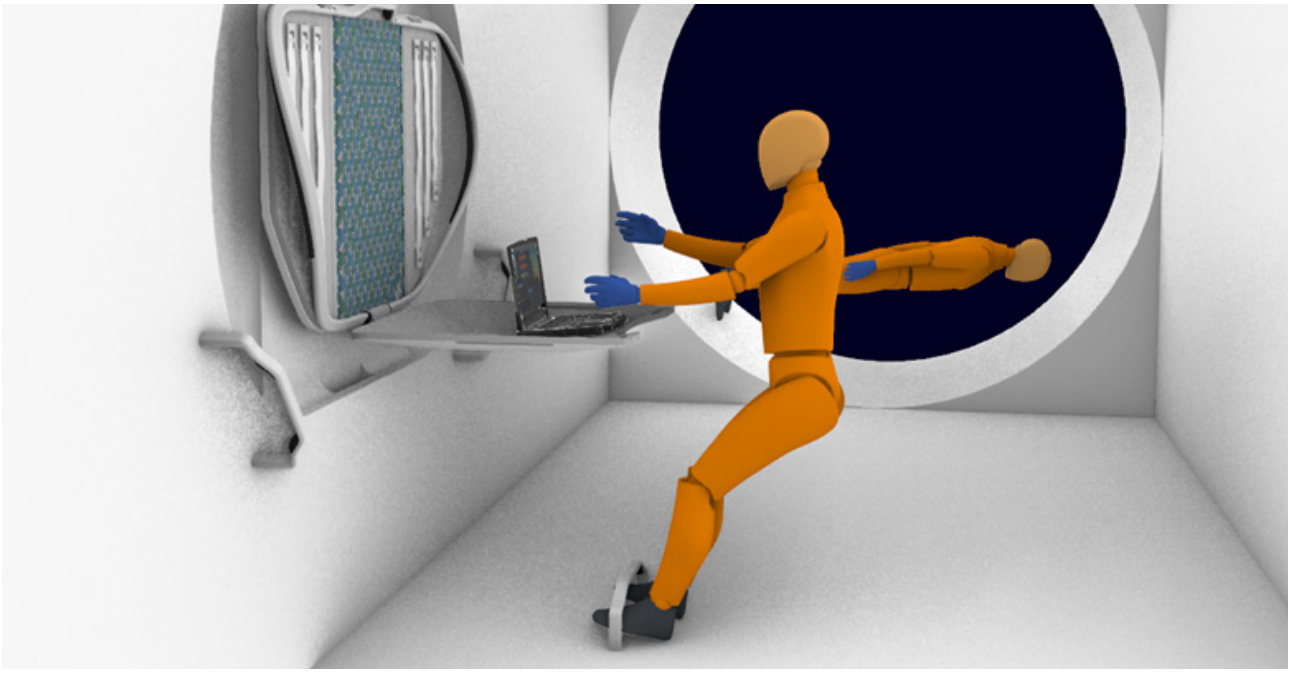
When pulled out and table top is opened to 180 degree the place can accommodate 10 people comfortably.

So once extended, the table can accommodate more people. This table can comfortably seat 10 people. This is particularly useful for gatherings, dinners, or special occasions where more seating is needed.

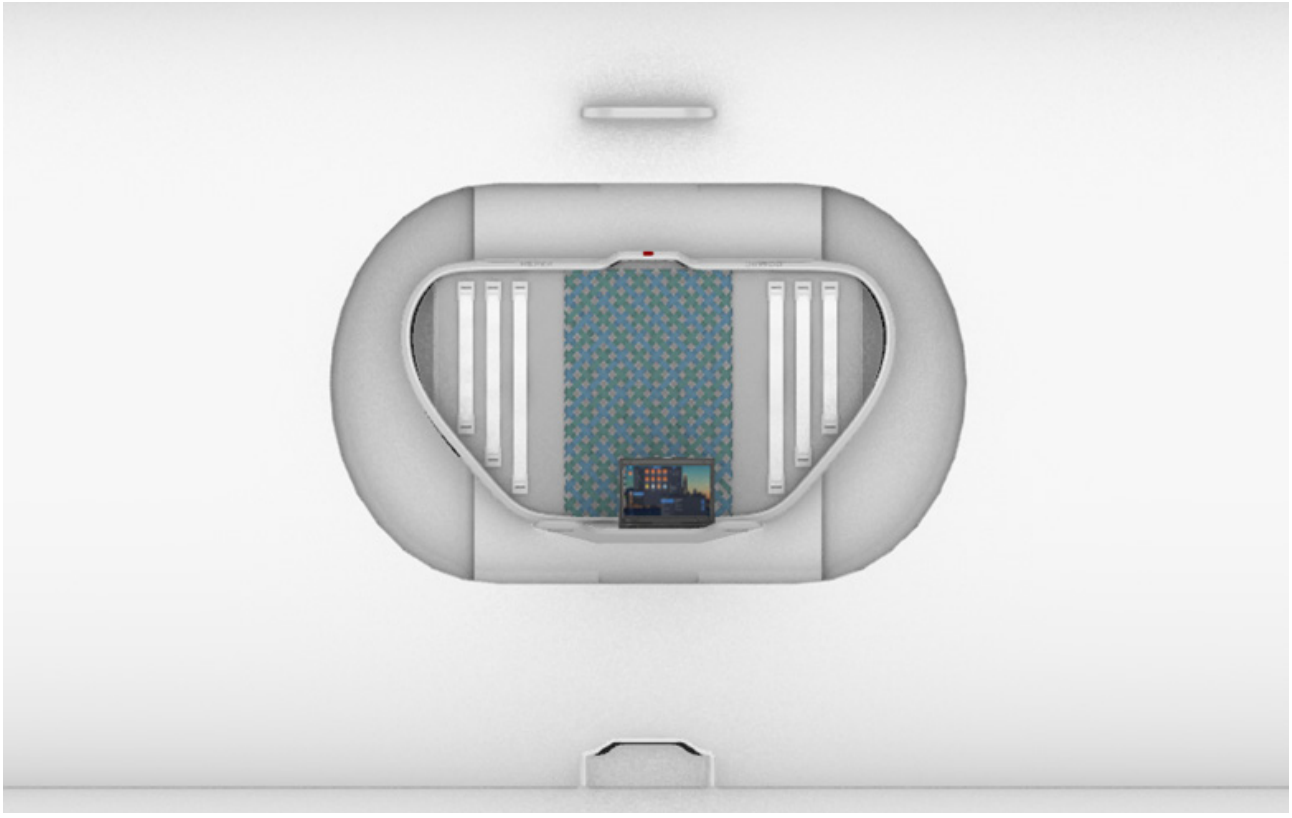
It is a smart solution for space-saving and flexibility in dining areas, combining functionality with style to adapt to different needs.

3. Pushed in with table top opened 90 degree (perspective will turn 90 degrees clockwise):

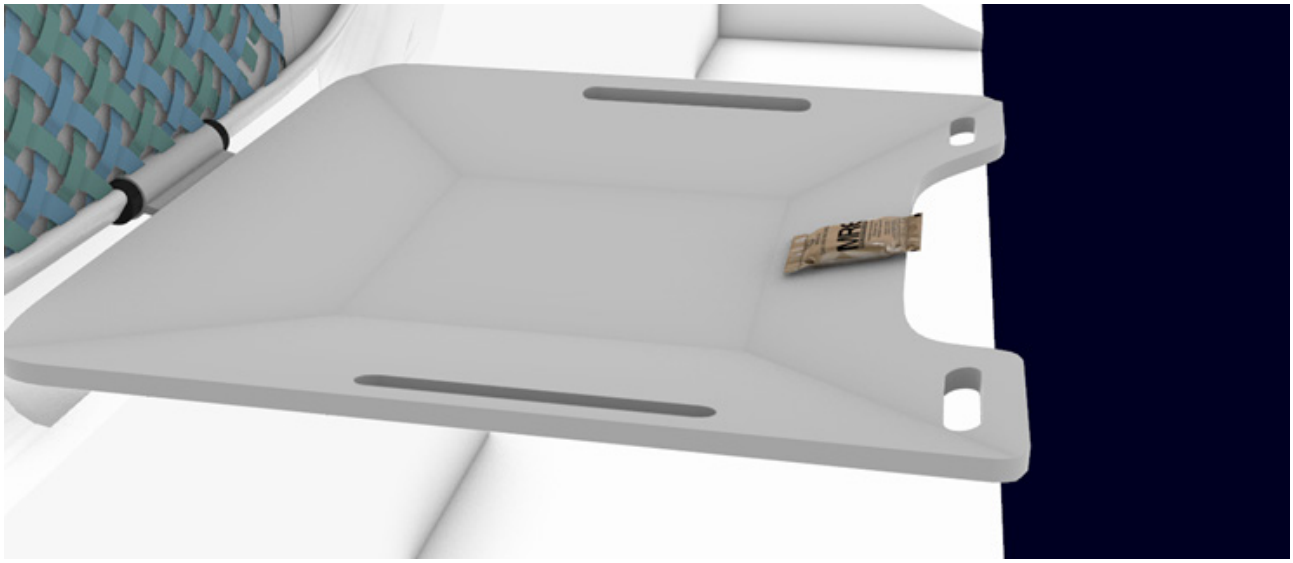




Let's Rotate our perspective 90 degree clockwise. Now the table is pushed and it make a lot of space around, the table top can be rotated and locked at 90 degree and setup can accommodate minimum 3 people easily.



When only the table top is opened it creates a unique way to put things on it. As it is an angled top it makes it easy to access the food,



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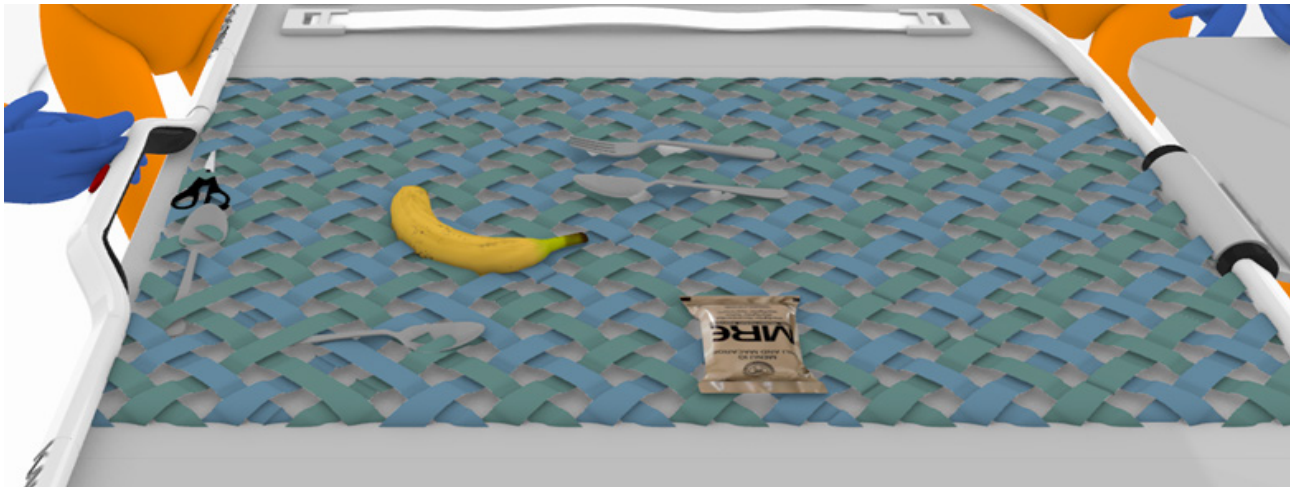
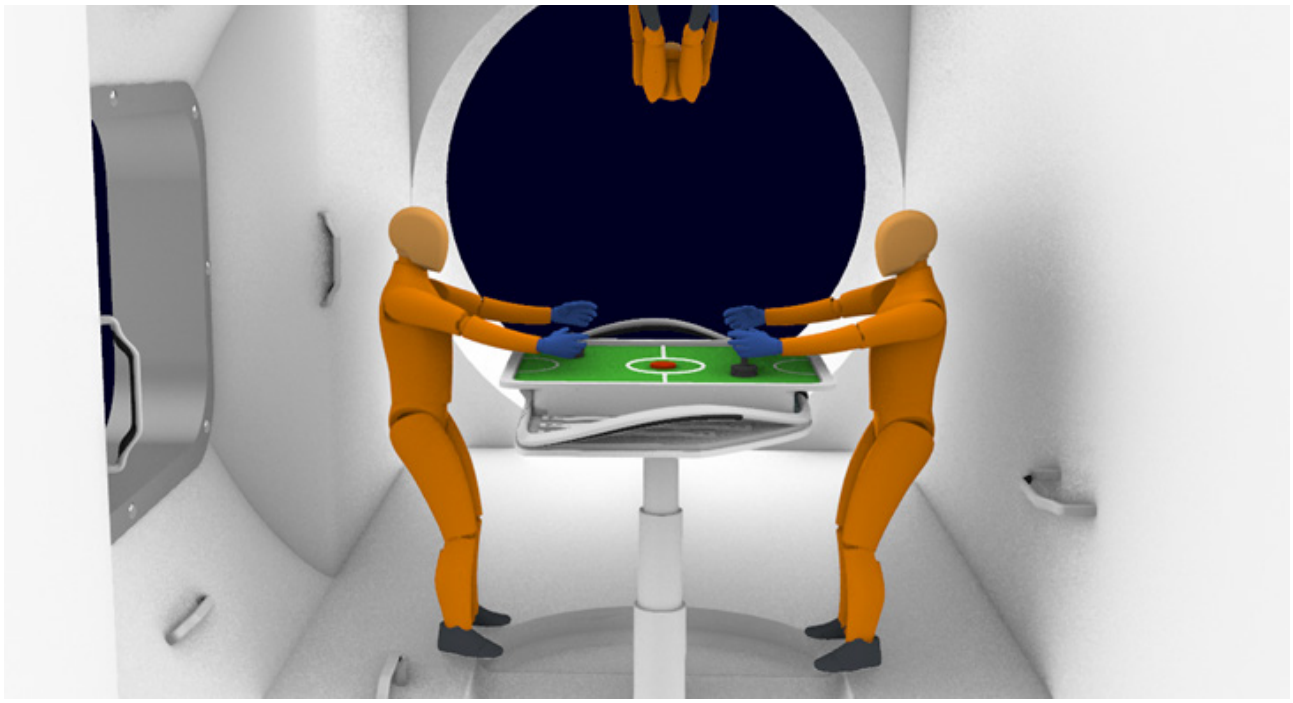


4. The Add-ons:



Space Hockey:

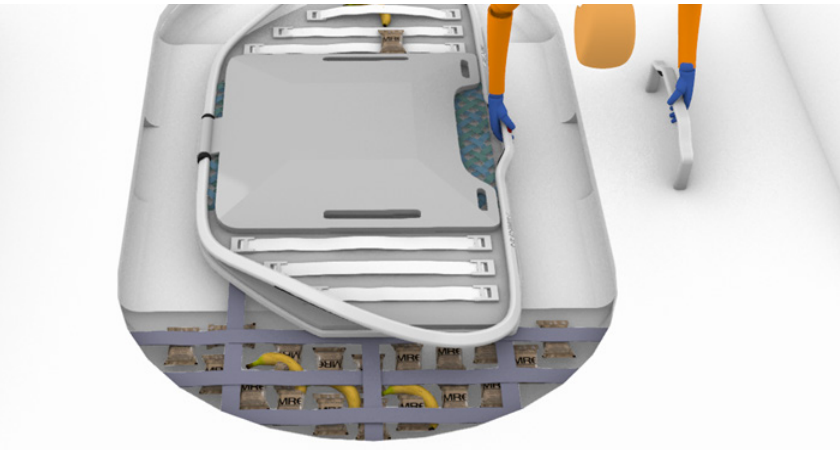
In this tabletop game, the playing surface has special gaps designed for the add-ons to interact with. These gaps serve a dual purpose: they allow the add-ons to be securely attached to the tabletop and also provide rotational freedom for the table top. These add-ons can be different games, such as space pinball or, in this case space air hockey. The exciting part is that despite being different games, they all share the same basic rules and gameplay mechanics.

Now, let's dive into the space air hockey add-on. Inside this add-on, there's a unique setup to keep the game components neatly contained. Specifically, the air hockey puck and two air hockey strikers are placed beneath a sheet of toughened glass. This design ensures that everything stays within a closed compartment, preventing pieces from getting lost and keeping the game organized.

Here's how you play the space air hockey add-on: To control the air hockey strikers, each of them comes equipped with a magnetic handle. These magnetic handles are the rest of the striker's structure, and they're designed to be attached to each other using magnets. This means that you can easily join the handles to the striker inside the glass, creating a single, longer handle for each player which they can control.

In summary, the add-ons in this tabletop game enhance the gaming experience by providing different game options like space air hockey. The design keeps all components secure under toughened glass and introduces a magnetic handle system for the strikers, making gameplay both exciting and challenging. It's a creative way to enjoy various games on the same tabletop while maintaining a tidy and organized setup.

Optional Storage:

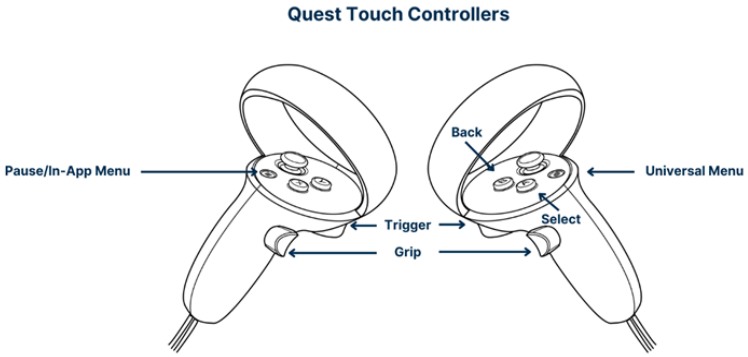


Net mesh is widely used in space station to keep things organized, It is easy to install, easy to maintain, easy to replace if something breaks and lightweight. So here the bottom space can function as a storage space as well.

User Interaction with VR:

The interaction with VR is tricky, I used meta quest 2 and let's dive into how it works

When you get into the game your right-hand controller will work as your right hand inside the VR and left-hand controller will work as your left hand. Let's take a look at how everything works.



To turn around – Right hand thumbstick

To move around – Left hand thumbstick

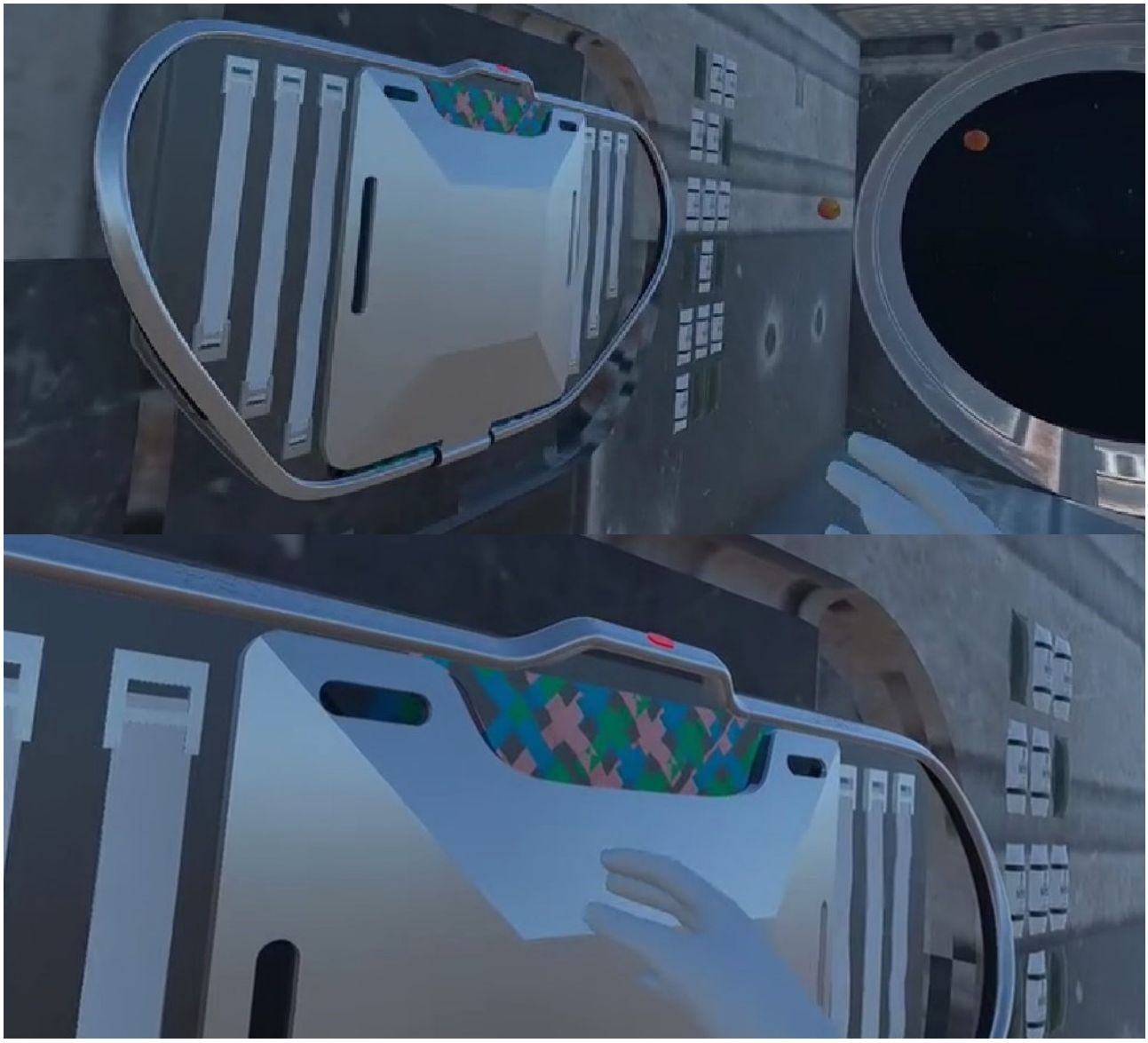
To grab an object – Use the grip button and keep grabbing, if you release it will float away

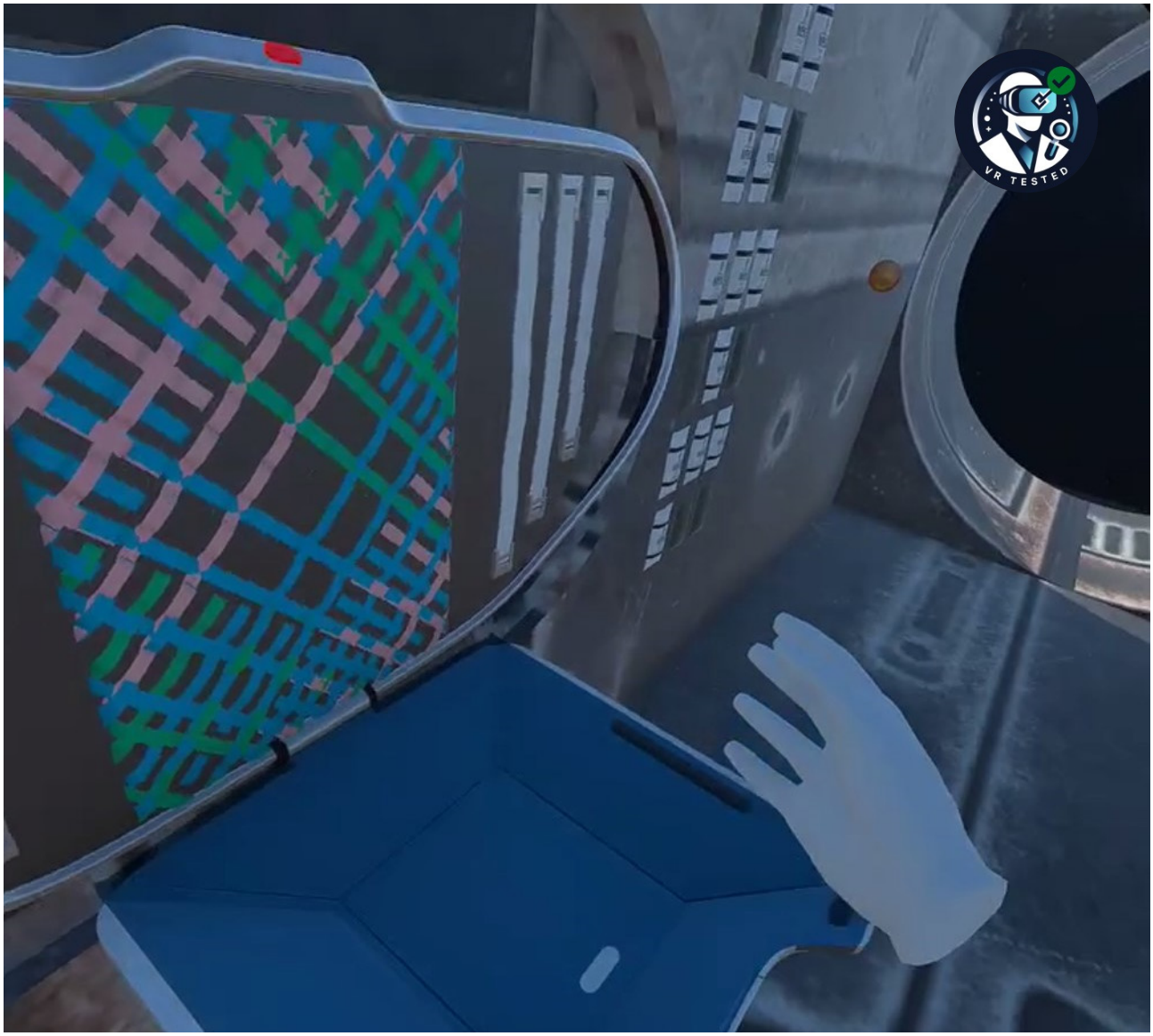
To throw an object – Grab the object using grip button and then throw and release the grip button

The fly function – If you use left thumbstick and move, it will take you to the direction where you are looking, weather it is up, down, front, back, left, right.

Because of Zero Gravity, everything floats including the player.
You can grab different items and throw around.

Approaching the table when perspective is turned 90 degree clockwise.



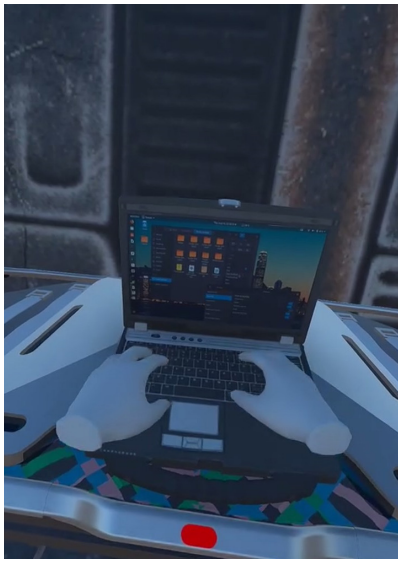


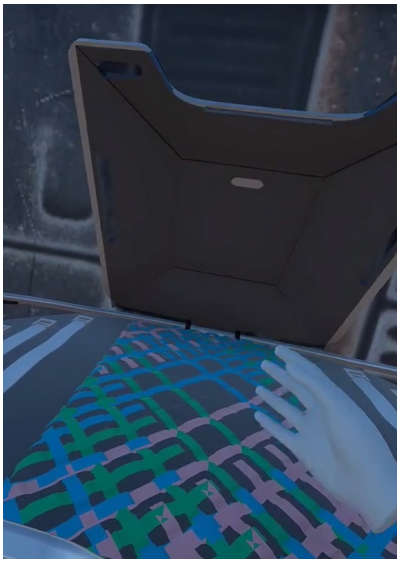
Opening the table top

Can be used for eating or working, the cut out helps the user come a little closer inside the table so that one can work comfortably. Can accomodate 3 people easily. Easy to open and close

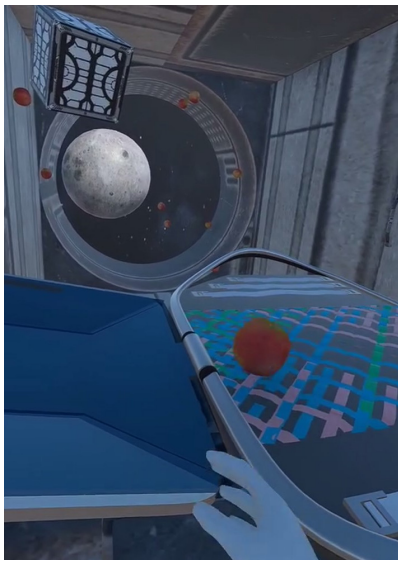
The food can be grabbed and then either be stuck on the top of the elastic band with the help of velcro or put under the band.v.

Opening the table





When table pulled out laptop can be used on top of it, if more astronauts are around the table top can be rotated 180 for more space.



Space between table top and main table is also used for storage of different things like food, scissor, spoon etc. The window gives a great view when eating or working.

In essence, the final design proposal of the zero-gravity dining table with VR integration is a detailed and polished presentation of the product. It combines technical details with user-focused design, showcasing a solution that is not only innovative and suited for space but also practical and user-friendly. This proposal serves as the blueprint for bringing the concept to life and marks a significant milestone in the journey from idea to reality.

7.2 Materials, Form, and Technology

Materials, Form, and Technology

In the context of designing a zero-gravity dining table with Virtual Reality (VR) integration, the terms "Materials, Form, and Technology" refer to the essential components that make up the design and functionality of your product. Let's explain each of these aspects in detail in simple and clear language:

Materials:

For the development of Dining Table PEEK Carbon Fiber is being used with stretchable plastic net mesh and the stretchable straps have Velcro on top that has loop side on it. The hook side of Velcro must be put on the things that needs to be locked with the table.

The Dining table is made using PEEK (Polyether ether ketone) carbon fiber, which is a high-performance engineering plastic known for its strength, heat resistance, and chemical resistance. This material makes the table both sturdy and long-lasting.

In addition to the carbon fiber structure, the table incorporates a stretchable plastic net mesh. This mesh could serve multiple purposes, such as providing a flexible area for storage or adaptability in shape and size for different items placed on or near the table.

Moreover, the table features stretchable straps with Velcro. Velcro has two components: a hook side and a loop side. In this design, the loop side of the Velcro is attached to the top of the straps. These straps can be used to secure items to the table, enhancing the table's functionality. For instance, if you want to keep tableware, decorations, or any objects stable on the table, you can use these straps to lock them in place. The hook side of the Velcro would be on the objects you want to secure, which would adhere to the loop side on the straps, creating a firm hold.

This makes the design innovative and versatile, blending the durability and high-tech qualities of carbon fiber with the practicality and flexibility of the Velcro-attached stretchable straps and net mesh. Other than space station It could be particularly useful in environments where stability and adaptability of table space are essential, such as in outdoor settings, on boats, in RVs, or even in homes where space is a premium and furniture needs to be multifunctional.

Materials

Component	Material	Safety Factor
Body1	PEKK - Polyetherketoneketone Reinforced With Carbon Fibers - HT-23 (with EOS P 810 3D Printer)	Yield Strength

PEKK - Polyetherketoneketone Reinforced With Carbon Fibers - HT-23 (with EOS P 810 3D Printer)

Density	1.390E-06 kg / mm^3
Young's Modulus	5800.00 MPa
Poisson's Ratio	0.34
Yield Strength	61.00 MPa
Ultimate Tensile Strength	61.00 MPa
Thermal Conductivity	4.600E-04 W / (mm C)
Thermal Expansion Coefficient	3.855E-05 / C
Specific Heat	970.00 J / (kg C)

Force1

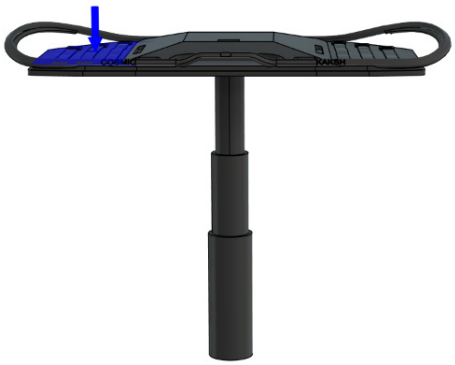
Type	Force
Magnitude	10000.00 N
X Value	0.00 N
Y Value	0.00 N
Z Value	-10000.00 N
Force Per Entity	No

Selected Entities

Force2

Type	Force
Magnitude	10000.00 N
X Value	0.00 N
Y Value	0.00 N
Z Value	-10000.00 N
Force Per Entity	No

Selected Entities



Results

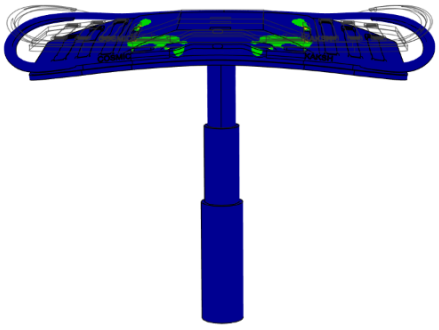
Result Summary

Name	Minimum	Maximum
Safety Factor		
Safety Factor (Per Body)	1.32	15.00
Stress		
von Mises	0.011 MPa	46.217 MPa
1st Principal	-10.891 MPa	52.983 MPa
3rd Principal	-42.319 MPa	4.387 MPa
Normal XX	-37.804 MPa	45.058 MPa
Normal YY	-24.795 MPa	18.639 MPa
Normal ZZ	-16.567 MPa	12.426 MPa
Shear XY	-14.73 MPa	12.781 MPa
Shear YZ	-10.033 MPa	8.137 MPa
Shear ZX	-13.536 MPa	14.848 MPa
Displacement		
Total	0.00 mm	20.20 mm
X	-2.27 mm	2.277 mm
Y	-5.981 mm	8.578E-04 mm
Z	-19.75 mm	3.317 mm
Reaction Force		
Total	0.00 N	2228.645 N
X	-499.027 N	523.633 N
Y	-311.011 N	823.449 N
Z	-324.709 N	2225.981 N
Strain		
Equivalent	2.688E-06	0.011
1st Principal	1.760E-06	0.012
3rd Principal	-0.009	6.367E-06
Normal XX	-0.005	0.006
Normal YY	-0.003	0.003
Normal ZZ	-0.002	0.002
Shear XY	-0.007	0.006
Shear YZ	-0.005	0.004
Shear ZX	-0.006	0.007
Contact Force		
Total	0.00 N	0.00 N
X	0.00 N	0.00 N
Y	0.00 N	0.00 N
Z	0.00 N	0.00 N

Safety Factor

Safety Factor (Per Body)

0.00 8.00



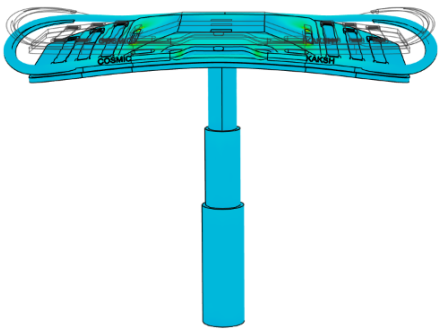
Stress

von Mises

[MPa] 0.011 46.217

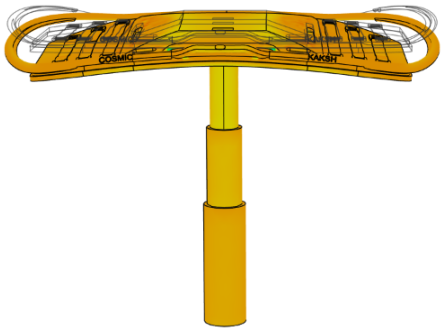
1st Principal

[MPa] -10.891 52.983



3rd Principal

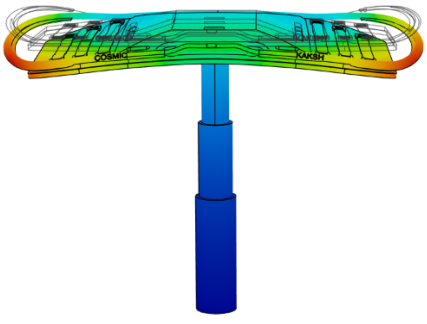
[MPa] -42.319 4.387



Displacement

Total

[mm] 0.00 20.20



Imagine a small car, like a compact sedan. The weight of such a car, exerting force downwards due to gravity, can be close to 10,000 Newtons. This helps in understanding the magnitude of this force and the table made of PEEK Carbon Fiber can handle that.

Form:

Design for Zero Gravity: The form or shape of the dining table is be designed specifically for use in zero gravity that prevent items from floating away and ensure ease of use for astronauts in a weightless environment.

Ergonomic and Space-Efficient: The table is ergonomically designed for comfort and efficiency in the limited space of a spacecraft or space station.

Aesthetics: While functionality is critical, the aesthetic aspect of the table is also taken into consideration. A design is visually appealing which can enhance the overall experience.

Technology:

The Table pull handle mechanism is a simple yet clever design that allows for easy maneuverability of the suitcase while maintaining a compact form when not in use. Here's how it generally works:

Components of the Pull Handle Mechanism:

1. Telescopic Handle: The most visible part of the mechanism, usually consisting of two or more segments that slide into each other. This design allows the handle to be extended to a comfortable pulling height and retracted for storage.

2. Locking Mechanism: This is crucial for maintaining the handle at the desired height. Commonly, a push-button mechanism is used, which, when pressed, unlocks the segments allowing them to slide. Releasing the button locks the segments into place.

3. Internal Tracks and Guide Channels: Inside the table, there are tracks and guide channels that guide the telescopic handle as it extends and retracts. These ensure the handle moves smoothly and stays aligned.

4. Springs: Springs are often part of the locking mechanism. They provide the necessary tension to keep the handle locked in position and assist in the retraction process when unlocked.

How It Works:

1. Extension: When you need to use the handle, you typically press a button located on the handle itself. This button is connected to the locking mechanism inside the handle. Pressing it disengages the locks that hold the telescopic segments in place, allowing them to slide.

2. Adjusting Height: As you pull the handle up, the segments slide out of each other. When you reach the desired height, you release the button. The locking mechanism, often a series of pins or latches, engages with holes or notches on the segments, locking them in place.

3. Retraction: To retract the handle, you press the button again, which disengages the locking mechanism. Then, you can push the handle down. The segments slide back into each other. In some designs, springs assist this retraction to make it smoother.

4. Storage: Once fully retracted, the handle fits into a molded cavity, making it compact for storage.

The pull handle mechanism in Dining Table is an excellent example of practical engineering designed to improve user convenience and functionality in a compact form. Despite its simplicity, it requires precise engineering to ensure reliability and ease of use.

Integration of VR: The technology component primarily refers to the integration of VR into the dining experience. This includes VR headsets, software for creating virtual environments, and any additional sensors or controls needed.

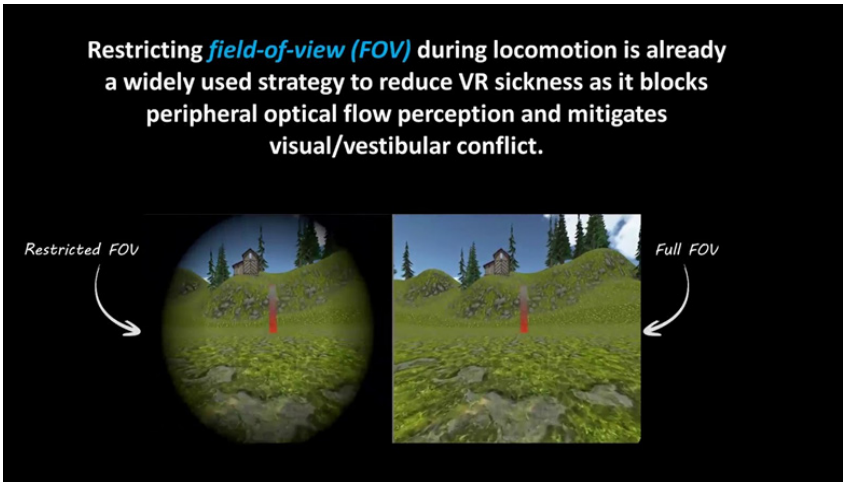
User-Friendly Interface: The VR technology should be user-friendly, considering that astronauts might be using it in a challenging environment. This means simple, intuitive controls and easy access to VR equipment.

Advanced Features: Depending on the scope of your project, the technology might also include advanced features like personalized virtual environments, interactive elements in the VR experience, or even augmented reality (AR) integrations.

Compatibility and Safety: The technology used must be compatible with the spacecraft's systems and meet all safety standards required for space equipment.

In summary, the "Materials, Form, and Technology" of your zero-gravity dining table with VR integration are interconnected aspects that define the product. The materials need to be carefully chosen for their suitability in space, the form must address the unique challenges of zero gravity and space constraints, and the technology must enhance the dining experience while being safe and easy to use. Balancing these three components is key to creating a product that is not only innovative and functional but also practical and enjoyable for its users.

7.3 Addressing Zero-Gravity Challenges and Enhancing with VR


Restricting field-of-view (FOV) during locomotion is already a widely used strategy to reduce VR sickness as it blocks peripheral optical flow perception and mitigates visual/vestibular conflict.
Restricted FOV
Full FOV

Addressing Zero-Gravity Challenges and Enhancing with VR
There are many challenges people face while using VR headset –

1. Motion Sickness:

- Problem: Users may experience nausea and dizziness due to the disconnect between visual input and bodily sensations.
- Solution: Gradually increase VR exposure, select comfortable content, and consider motion sickness remedies.

2. Eye Strain and Fatigue:

- Problem: Prolonged use can lead to headaches and eye discomfort.
- Solution: Take regular breaks, adjust brightness and contrast settings, and ensure the headset fits well.

3. Spatial Awareness:

- Problem: VR headsets can make users unaware of their real-world surroundings, leading to accidents.
- Solution: Use a dedicated, obstacle-free space and utilize VR systems' boundary features.

4. Discomfort and Ergonomics:

- Problem: Extended use can cause neck strain and general discomfort.
- Solution: Opt for ergonomic, lightweight headsets, add extra padding, and adjust straps for comfort.

5. Limited Field of View:

- Problem: Some headsets have a restricted field of view, impacting the immersive experience.
- Solution: Research headsets with wider fields of view and properly adjust the headset for optimal vision.

6. Hardware Limitations:

- Problem: High-quality VR requires expensive hardware; lower-end systems might offer subpar experiences.
- Solution: Invest in quality hardware if possible and optimize settings for a balance between performance and visual quality.

7. Technical Issues:

- Problem: Glitches, lag, or tracking problems can disrupt the experience.
- Solution: Keep software updated and regularly calibrate equipment.

8. Social Isolation:

- Problem: Prolonged VR use can lead to reduced real-world social interaction.
- Solution: Set time limits for VR use, balance with real-life activities, and explore social VR platforms.

9. Health Concerns:

- Problem: There are concerns about the long-term effects of VR on vision.
- Solution: Limit VR time, especially for children, and consult eye care professionals for guidance.

10. Adaptation Period:

- Problem: New users may find it challenging to get used to VR controls and environment.
- Solution: Start with simple applications and practice regularly to become more comfortable.

By addressing these challenges with the respective solutions, I tried to enhance the VR experience, making it safer, more comfortable, and more enjoyable.

8. Final Results and Conclusion

8.1 Summary of Findings

In this project, I successfully designed and developed an innovative zero-gravity dining table, integrated with Virtual Reality (VR), marking a significant stride in the realm of space habitation. My design combined functionality with cutting-edge technology, making it a noteworthy achievement in designing for extreme environments. The key features of my design addressed the challenges of zero gravity effectively, using advanced magnetic and Velcro systems to secure items, and an ergonomic design tailored for the unique constraints of space. The table's multifunctional nature supports various activities, adeptly addressing the spatial limitations of space habitats and enhancing the quality of life on space missions.

During the testing phase, conducted in simulated zero-gravity environments, my prototype excelled in functionality and usability. This performance demonstrated its resilience and adaptability, mirroring the conditions of space. The integration of VR within the dining experience was transformative, contributing significantly to the psychological welfare of astronauts. The feedback I received from astronauts and space engineering experts was highly encouraging. They lauded the table for its practicality, comfort, and adaptability, underscoring its capacity to enrich daily routines in space. The VR component, in particular, was applauded for its innovation in dining, providing a multifaceted experience that enhances mental and emotional well-being.

I am proud to say that the project met its objectives, effectively addressing the unique challenges of dining in zero gravity and integrating VR technology to elevate the dining experience. This project wasn't just about solving practical issues; it also significantly enhanced the psychological aspects of space missions. My design stands out for its innovative integration of VR into space dining, setting a new benchmark in habitat design. Its strengths lie in its user-friendly interface, ergonomic attributes, and the psychological benefits provided by the immersive VR environment, which collectively enhance astronaut morale.

However, the journey wasn't without its challenges. Optimizing space utilization and ensuring compatibility with space equipment were significant hurdles. Designing for the unique conditions of a zero-gravity environment required innovative thinking and creativity. The project was an invaluable learning experience, offering deep insights into user-centric design, adaptation to extreme conditions, and the integration of technologies like VR in unique environments.

Looking ahead, I believe this project has the potential to significantly influence future designs in space habitat. It emphasizes comfort and well-being in extreme environments and opens up new possibilities for living solutions in space and other extreme settings. My work contributes notably to the fields of space habitation and VR technology, advancing our understanding and capabilities in designing for space. Further refinement of the design, exploration of different VR environments, and testing in real space missions are steps I look forward to, as they will continue to advance this groundbreaking field.

This conclusion reflects my personal journey through the project, highlighting my achievements, the challenges I faced, and the potential impact my work could have on future space habitation and technology.

8.2 Implications for the Field

When we talk about the "Implications for the Field" in the context of your project on a zero-gravity dining table with Virtual Reality (VR) integration, we're discussing how my work might influence or contribute to the broader field of space technology, interior design for spacecraft, and VR application. Let's explore what this means in simple and detailed terms:

Advancements in Space Habitat Design

Innovative Living Solutions: The project offers fresh ideas for living in space, particularly for dining in zero gravity. This can influence how future spacecraft and space stations are designed, emphasizing not just functionality but also the comfort and well-being of astronauts.

Space Efficiency: The design of the dining table, which likely incorporates space-saving features, provides insights into efficient use of space. This is crucial in spacecraft design where every inch counts.

Enhancements in Astronaut Well-being

Psychological Benefits: By integrating Add-ons into the dining experience, the project highlights the importance of psychological well-being for astronauts. It shows how games can be used to create a sense of normalcy and relaxation in the challenging environment of space.

Social and Recreational Aspects: The design also opens up possibilities for improving the social and recreational aspects of space missions. Many component can offer interactive experiences that could help reduce feelings of isolation in space.

Impacts on VR Technology

Expanding VR Applications: The project demonstrates a novel application of VR technology. It sets an example of how VR can be used in unique and challenging environments, pushing the boundaries of where and how VR can be implemented.

User Experience Insights: The feedback and data gathered from astronauts using the VR system provide valuable insights into user experience design. This can influence how VR is designed for other complex environments.

Contributions to Material Science and Safety

Material Innovation: The materials chosen for the dining table need to be lightweight, durable, and safe for space use. This project can contribute to the field of material science by showcasing innovative uses of materials or inspiring new material development.

Enhancing Safety Standards: By addressing the unique safety challenges of a zero-gravity environment, the project could influence safety standards and practices in spacecraft design and habitation.

Broader Technological and Design Implications

Interdisciplinary Collaboration: This project exemplifies the value of interdisciplinary collaboration, combining interior design, technology, psychology, and aerospace engineering. This approach can inspire similar collaborations in other fields.

In summary, the implications of your project for the field extend far beyond just a new piece of furniture for space. It represents a step forward in space habitat design, a new application of VR technology, and contributes to our understanding of living in extreme environments. This project not only addresses the practical needs of space travel but also considers the psychological and social needs of astronauts, potentially influencing future missions and designs in space technology.

8.3 Future Research Directions

There are many ways we can build further for space

1. VR Zero gravity simulation:

To make zero gravity simulation more realistic we can put people with VR Headset on a Zero Gravity Motion simulation (Like an Aerotrim) that moves and rotates according the players in the Zero Gravity Simulation. This will also help the astronauts in training before their mission.

2. Designing Add-ons:

More add-ons can be designed which will engage astronauts further in their free time and make a stronger bond between the. Some Ideas are

A. Space Casino
B. Space Pinball
C. Space laser tag
D. Space Target Practice.

This is a common game which can be used in space, It uses the same principal which is being used in space station. The velcro, The board's surface is made of loop part and ball has hook attached to it.

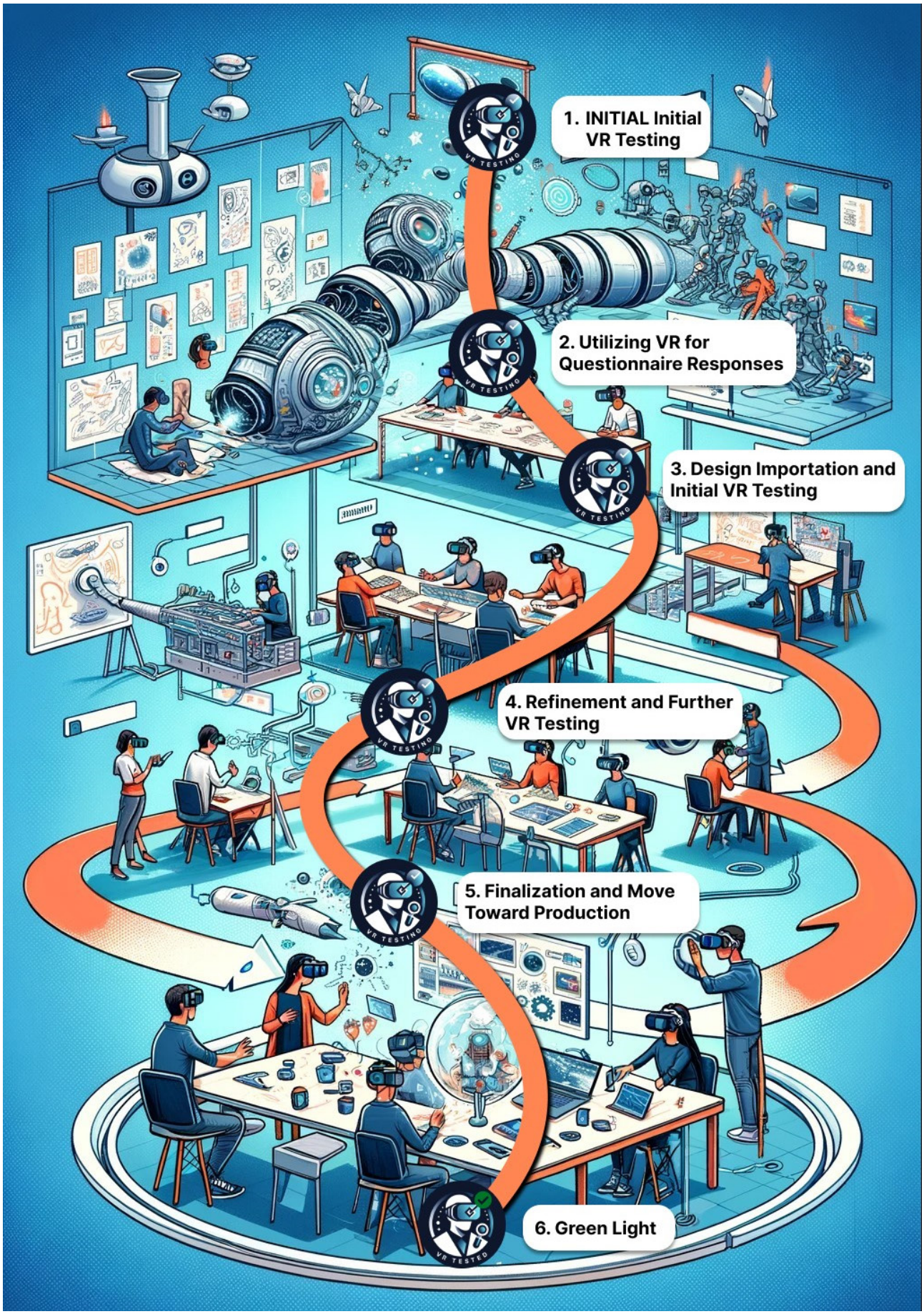
3. Sleeping quarters:

The sleeping quarter is one of the other everyday used things that can be designed for astronauts.

4. Design inspiration:

As it has always been the technology that comes down from space grade to military grade to industrial grade. Like Teflon a technology came down from space to our homes this table design can also come down and can be used with little modification in Motor Homes, Trains and buses.

8.4 Incorporation of VR in the Project Pipeline


1. INITIAL Initial VR Testing
2. Utilizing VR for Questionnaire Responses
3. Design Importation and Initial VR Testing
4. Refinement and Further VR Testing
5. Finalization and Move Toward Production
6. Green Light
VR TESTING
VR TESTED

The incorporation of Virtual Reality (VR) into the project pipeline for enhancing the zero-gravity dining table design involved a systematic and multi-phased approach:

1. Initial VR Testing Using Existing Simulation:

- In the initial phase, I utilized an existing VR simulation available on the Meta Quest store named "Mission ISS". This simulation provided a realistic depiction of the current dining table setup in the space station.
- I crafted questionnaires based on this simulation to understand user interactions and experiences with the existing setup. This step was crucial in identifying areas of improvement for the dining table.

2. Utilizing VR for Questionnaire Responses:

- To gather insightful answers, VR played a crucial role in helping respondents fully comprehend the intricacies of the existing table and the zero-gravity environment.
- This immersive experience allowed individuals to provide informed and detailed feedback on the existing design, which was instrumental in guiding the redesign process.

3. Design Importation and Initial VR Testing:

- After collecting opinions from questionnaires and industry experts, I imported the first design iteration into the VR environment for testing.
- This initial testing phase revealed several gaps and problems in the design. The immersive nature of VR allowed for a deeper understanding of how the table would function in a zero-gravity environment, leading to more targeted improvements.

4. Refinement and Further VR Testing:

- Based on the insights gained, I refined the table design, addressing the identified issues.
- The new, finalized design was then put through another round of VR testing. This stage was crucial for validating the improvements and ensuring the table's functionality and usability in a simulated zero-gravity environment.
- User feedback during this phase played a significant role in fine-tuning the design, ensuring that it met the needs and expectations of potential users in a space setting.

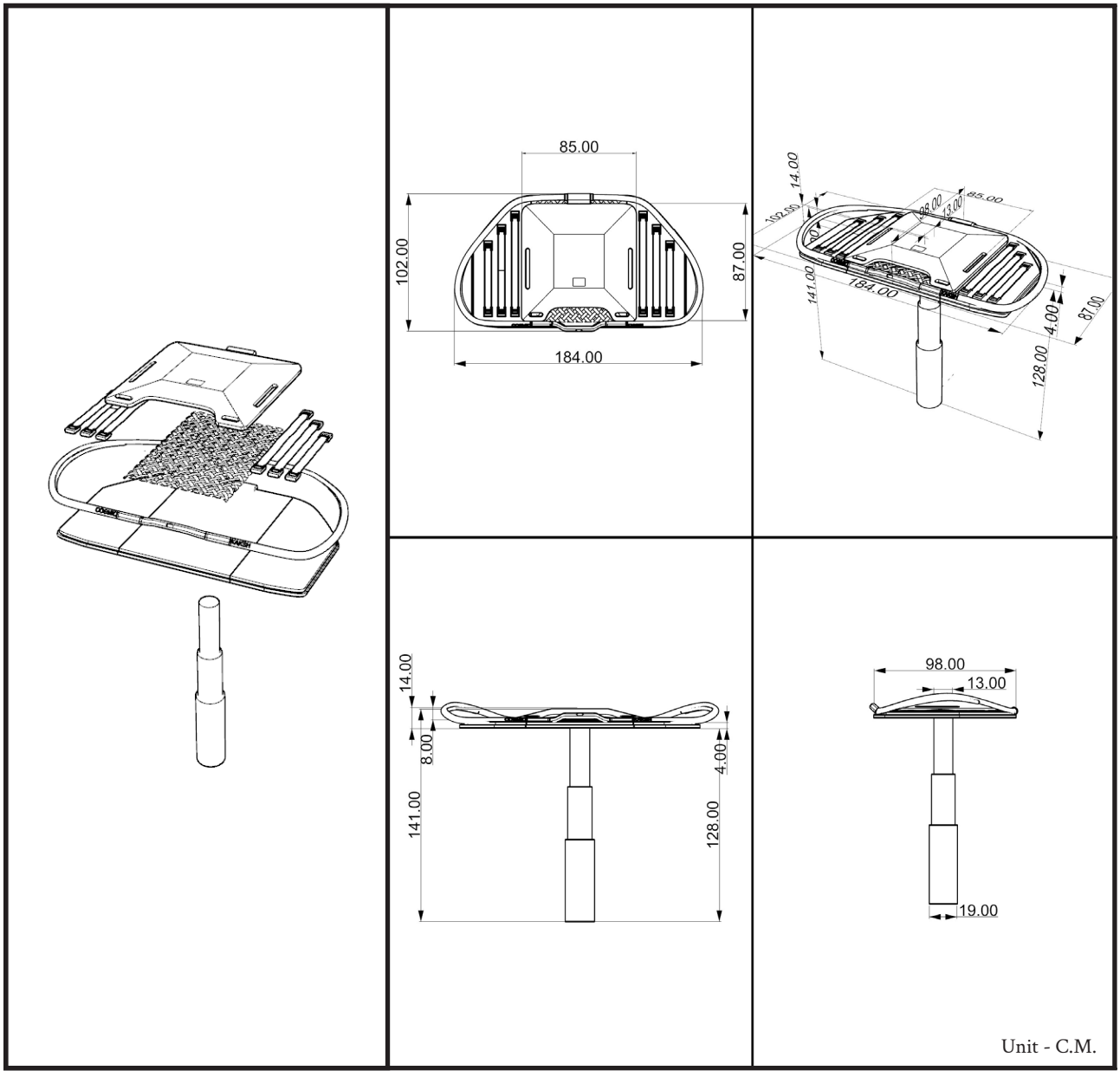
5. Finalization and Move Toward Production:

- After rigorous testing and refinement through VR, the design was finalized, marking the completion of the development phase.
- The use of VR throughout the project pipeline not only facilitated a thorough understanding of the user experience in a zero-gravity environment but also significantly informed the design process, leading to a well-rounded and functional dining table ready for production.

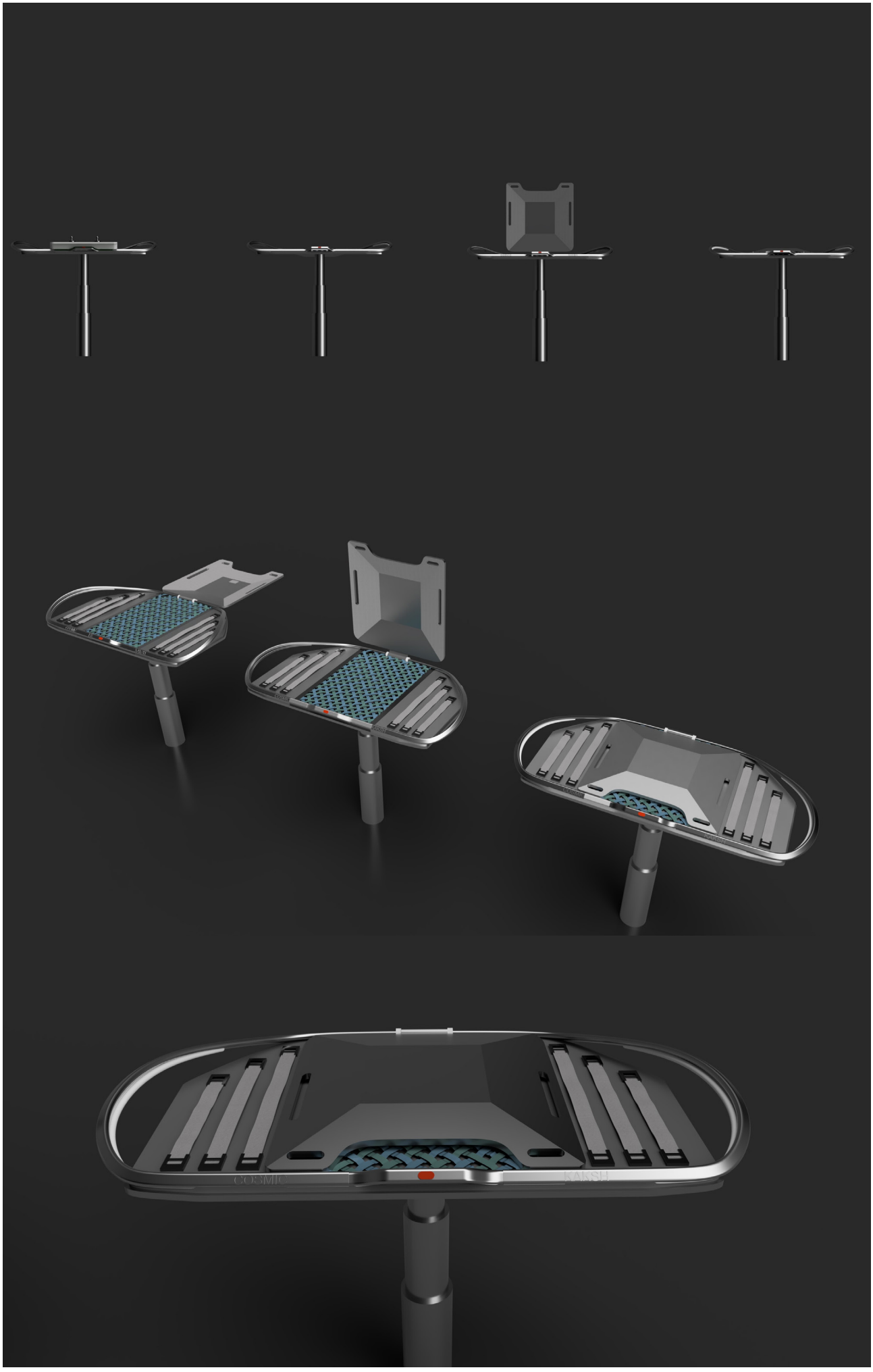
In summary, VR was an integral tool in the development pipeline, from initial analysis and understanding of the current setup in the space station to the design, testing, and finalization of the new zero-gravity dining table. It provided an immersive platform for both gathering user feedback and conducting iterative testing, ensuring the final design was both innovative and well-suited to the unique conditions of space.

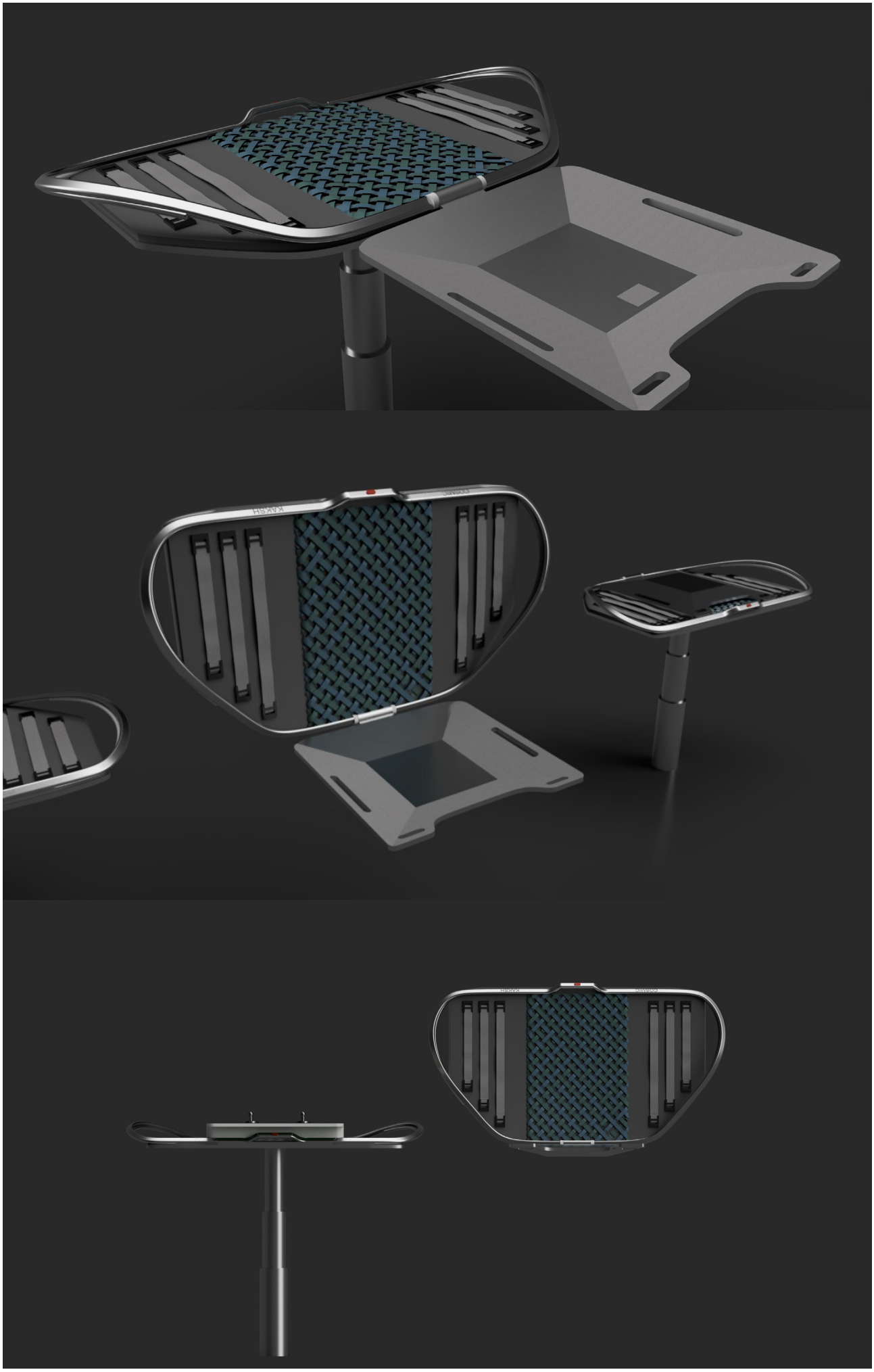
Appendices

- A.1 Technical Drawings



- A.2 Renders


COSMIC
KAKSH



COSMIC

- A.3 Extras

4.50
Handles with soft grip

SOCKS with bulges on front and back so that it can fit under the handrail easily.. The padding on top also helps with keeping things soft on contact.

REFERENCES

Virtual Reality toolkit

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Space Station Dining Table - Iris Yao

NASA Space Station walkthrough

Unity VR Development Tutorials and Blog
FIST FULL OF SHRIMP

Dining in Space Station - Youtube Video

SAPIENZA
UNIVERSITÀ DI ROMA

Master of Science in
PRODUCT AND SERVICE DESIGN
a.y. 2022-2023

Final Work

Student
Ankush Gaharwar
ankushgaharwar@gmail.com

Supervisor
Michele Russo